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[*] Il presente contributo è stato preventivamente sottoposto a referaggio anonimo affidato ad un componente del Comitato di Referee secondo il Regolamento adottato da questa Rivista.

[1] Cass. Civ. n. 1906/2010; Cass. Civ. n. 17671/2009; Cass. Civ. n. 10071/2008; Cass. Civ. n. 6193/2008

[2] Nota a sentenza Tribunale Palermo, 14 febbraio 2006 *La capacità distintiva del marchio nella giurisprudenza* Giur. merito, fasc.1, 2007, pag. 73, di Geremia Casaburi

[3] A. Vanzetti, V. Di Cataldo, "Manuale di diritto industriale", Giuffrè Editore, 2012, pagg. 175 e ss, 250 e ss.

[4] *Marchio forte e marchio debole: Il caso "Havana Club"* (nota a Cass., sez. I, 16 aprile 2008 n. 10071), Dir. e giur. agr., fasc. 4, 2009, pag. 264, di Margherita Taldone

[5] Cass. Civ. n. 21601/2012

[6] *"L'acronimo è marchio debole non essendo linguaggio per neofiti"* (nota a: Cassazione Civile , 03 dicembre 2012, n.21601) Diritto e Giustizia online, fasc. 0, 2012, pag. 1162, di Stefano Liso

[7] A. Vanzetti, V. Di Cataldo, "Manuale di diritto industriale", Giuffrè Editore, 2012, pagg. 287 e ss.

[8] Cass. Civ. n. 29522/2008

[9]Cass. Civ. n. 17144/2009; Cass. Civ. n. 29775/2008; Cass. Civ. n. 6193/2008; Cass. Civ. n. 24909/2008

[10] Cass. Civ. n. 6193/2008

[11] A. Vanzetti, V. Di Cataldo, "Manuale di diritto industriale", Giuffrè Editore, 2012, pagg. 247 e ss.

[12] Cass. Civ. n. 1249/2013

[13] Corte Giust. CE, 12 giugno 2007, caso *Shaker* (A. Vanzetti, V. Di Cataldo, "Manuale di diritto industriale", Giuffrè Editore, 2012, pag. 249)

[14] Tribunale di Napoli 20/01/2014; Tribunale di Catania 04/03/2003.

A game-theory perspective on market cooperation

di

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Abstract

This paper contributes to the literature on market cooperation. It draws on influential works from this field in order to support the presentation of a theoretical model in conjunction with a mathematical formulation. The model represents a synthesis of the ideas and concepts discussed, and act as a focus for subsequent discussion. The mathematical formulation aims to shed light on the possibility that features of the interaction patterns in conjunction with prior exchange history may promote inter-firm cooperation. Non-cooperative game theory provides the theoretical foundation for the analysis. The mathematical formulation examines two different contexts: game with Perfect Monitoring and game with Imperfect Monitoring.

Summary: 1. Introduction – 2. Theoretical frameworw – 2.1. An overview of the iterated Prisoner's Dilemma – 2.2 Anticipated and previous interaction in a game theory context: the shadow of the future and the shadow of the past - 3. The mathematical model - 3.1. The Perfect Monitoring game - 3.2. The Imperfect Monitoring game - 4. Discussion - 5. Limitations and implications for future research.

1. Introduction.

Research on inter-firm collaboration has traditionally explored the importance of organizational traits and fixed antecedents to cooperative relationships (Aiken and Hage 1968). Internal organizational characteristics, uncertainty and resource dependency have been alternatively considered as affecting levels and types of cooperation (Williamson 1975; Pfeffer and Salancik 1978).

Several researchers have called for an interactive approach to interorganizational relationships (Cook 1977; Levinthal and Fichman 1988). Such an approach emphasizes that interorganizational cooperation arises in the context of a specific relationship and unfolds through ongoing interaction (Heide and Miner 1992).

This study extends this perspective by exploring the additional possibility that features of the interaction patterns (i.e., *shadow of the future*) in conjunction with prior exchange history (i.e., *shadow of the past*) may encourage inter-firm cooperation. Following prior research, the *shadows of the past* and the *shadow of the future* are considered as impacting on cooperation through the mediating role

of interorganizational trust (Poppo, Zhou and Ryu 2008). The study proposes a theoretical model and a mathematical formulation expressing the aforementioned hypotheses.

The rational for this analysis is as follows. Mathematical modeling in the management field provides a common language that allows the comparison of related results in different contexts. Additionally, formal game theory framework provides an "audit trail" useful to distinguish between groundless assertions and logical propositions (Saloner 1991). That is why this study employs the iterated games framework to explore interorganizational cooperation in an industrial inter-firm setting. Non-cooperative game theory is adopted to formalize the interactions between buyer and supplier (Cachon and Netessine 2004). In addition, the study follows the recommendation of Heide and Miner (1992) to move from studies that primarily employ individual theories to research exploring multiple theories. Thus, both social exchange theories and an interactive model of relationships management provide theoretical foundation for the analysis.

The purpose of this inquiry is twofold. Firstly, the study aims to improve the understanding of interorganizational cooperation by means of interactive game theory. Secondly, the analysis further explores the potential value of mathematical modeling in the systematic study of interorganizational relationships.

The remainder of the article is organized as follows. The second section outlines the theoretical framework concerning the link between anticipated and prior interaction in an iterated game theoretic context. The third section presents the mathematical model considering two contexts: game with Perfect Monitoring and game with Imperfect Monitoring. The fourth section discusses the model formulation and the solutions obtained. Finally, the last section considers the implication of the findings along with the limitations of the analysis.

2. Theoretical framework.

Most theorists of interorganizational cooperation have emphasized the role of interdependency: parties may cooperate when they depend on each other or share assets (Pfeffer and Salancik 1978; Williamson 1985). Interactive theorists, in contrast, have often suggested that cooperation springs from the development of trust and commitment between two actors. Over time, the organizations – or the individual within them – come to care about their partners and to cooperate out of altruism rather than because of exogenous requirements (Heide and Miner 1992). Research from this viewpoint has properly begun to examine the effects of a relationship's history on levels of cooperation (Levinthal and Fichman 1988).

Recent studies integrate this theoretical position focusing on an additional possibility: indeterminate anticipated future interaction may promote cooperation (Heide and Miner 1992). This idea occurs in many researches but has been developed most precisely in the study of iterated games. Such possibility implies that the expectation of continuity ("the future") and the prior exchange history ("the past") have interdependent roles in determining the choice between cooperation or non cooperation (i.e., defection) in inter-firm contexts. Expanding recent developments in social exchange literature, the study recognizes that this cooperation/defection choice is mediated by the degree of trust (or distrust) between parties (Poppo *et al.* 2008).

There is some empirical evidence that anticipated future interaction and prior exchange history may sustain cooperation but there have been only a few systematic studies of this topic mostly at the organizational level of analysis. In addition, game theory has been frequently employed as a general framework, not addressing completely the potentiality of this analytical instrument. This paper aims to fill this gap developing a mathematical model of buyer-supplier relations that considers anticipated interactions, prior exchange history and interorganizational trust as impacting in different ways on cooperation. Figure 1 displays our framework.

The following two subsections explore in details the theoretical framework used to develop the conceptual model.

2.1. An overview of the iterated Prisoner's Dilemma.

In game theory, the Prisoner's Dilemma is a variation of a non-zero sum game in which two players may each "cooperate" with (C) or "defect" to (D) (i.e., cheat or betray) to the other player. This game can be applied to

describe the conflict between individual and collective interests in many different situations, such as inter-organizational relationships (Zagare 1984).

The basic assumption of this theory is that the only interest of each individual player is maximizing his own payoff, without any concern for the other player's payoff.

In the traditional form of the Prisoner's Dilemma game, two actors (players A and B) are suspected of a crime and arrested by the police. The police have insufficient evidence for convicting any of them. The players each choose whether to cooperate or defect in the absence of knowledge of what the other player will do. The incentive structure of the game is set up so that (1) it pays to defect no matter what you think the other player will do, but (2) if each player defects, they both end up with less than they would have got jointly choosing the cooperation. On one hand, the cooperating strategy is generally dominated by the defecting strategy, so that the only possible equilibrium for the game is for every player to defect. On the other hand, the equilibrium (D, D) is Pareto dominated by the issue (C, C). In other words, rational choice leads the two players to both play defect even though each player's individual reward would have been greater if they had both played cooperatively, thus the dilemma.

In the iterated Prisoner's Dilemma, the game is played repeatedly. Thus, each player has an opportunity to "punish" the other player for previous non-cooperative play. The incentive to defect can be overcome by the threat of punishment, leading to the possibility of a cooperative outcome (Fudenberg and Maskin 1986).

Exploring the repeated Prisoner's Dilemma game, we may consider five different factors as impacting on cooperation (Eriksson 2007).

- *The length of the game*. This factor depends on how many rounds the game consists of (i.e., how many times it is repeated). As a single Prisoner's Dilemma game has a unique Nash equilibrium in the outcome (D, D), in repeated Prisoner's Dilemma with a known final period the outcome – determined by backward induction – it will be the same (D, D) (Luce and Raiffa 1957). Only in an infinitely repeated game will mutual cooperation (C, C) emerge (Romp 1997), but only if the importance of future payoffs is high enough (Axelrod 1984). Different games can become connected if any of the players perceive them as such, or if the rules connect them. Long-term contracts, for example, connect subsequent games into a long series of rounds together constituting one extended game (Brandenburger and Nalebuff 1996). Games can also be connected without rules (i.e., contracts). Many

exchange parties enter the relationship with the expectation that they may interact again in the future, although neither party can predict how many times this will occur. In such cases, the relationship corresponds to an infinitely repeated Prisoner's Dilemma game (Hill 1990).

- *The size of the payoffs.* The size of the payoffs is crucial for the outcome of a game. In a repeated Prisoner's Dilemma, the chance of cooperation can increase when the difference between the temptation to defect and reward for mutual cooperation decreases, due to lower demands for the discount parameter. Payoffs for organizations depend on three basic factors: direct stakes (including financial solidity of a business and the size of the transaction); bargaining skills (experience leads to more accurate forecasts of negotiation outcomes); and management issues (including risk tolerance and time preference) (Reardon and Hasty 1996).

- *The discount factor.* In a repeated game, the discount factor is critical. It describes the importance of the next move relative to the current move. Future moves are less important than the current move since there may be no next move, and individuals prefer receiving payoff immediately rather than in the future.

- *The players' strategies.* In game theory, a strategy specifies what course of action a player pursues, given the history of the game. One strategy may be to always defect (i.e., *opportunistic strategy*), another to always cooperate (i.e., *altruistic strategy*). Strategy can also be sophisticated, as when a player uses the history of the game to model the behaviour of the other player and consequently uses probability theory to select the best long-term choice (Hill 1990). Rational players choose the strategy that leads to the largest payoffs. The most successful strategy is called *Tit-for-Tat*. It is based on reciprocity: starting with a cooperative choice and thereafter does whatever the other player did on the previous move (Axelrod 1984).

- *The amount of trust between players.* Empirical evidence shows that trust enhances cooperation in Prisoner's Dilemma (e.g., Lazar 2000). Trust decreases opportunistic behaviour, meaning that strategies become more focused on cooperation than defection. It also leads to less need for monitoring and control in long-term relationships, which decreases transaction costs (Hill 1990). This will increase the profits of future transactions (Parkhe 1993).

2.2. Anticipated and previous interaction in a game theory context: the shadow of the future and the shadow of the past.

The *shadow of the future* expresses the extent of anticipated interactions or expectation of continuity in an inter-firm economic exchange. It is a game-theoretical construct originally defined by Axelrod (1984: 124). The basic idea behind this concept is the following: when the expected payoff from cooperation outweighs the gain from self-interested behaviour, cooperation emerges through reciprocity (i.e., "first you act in a cooperative manner, then I do"). The stability of reciprocal acts of cooperation depends critically on sufficient value being placed on future returns and on the expected time horizon for future exchange (Telser 1980: 44). This game theoretical logic advances that the longer the expected time horizon, the higher the benefits from cooperation (Poppo *et al.* 2008).

Further work shows that cooperation may also occur when a non-zero probability of continuity exists. For example, both parties may adopt – though not necessarily communicate – a strategy that if the other ever acts opportunistically, they shift from a high cooperative return to a low return thereafter. When a party knows that it is in their best financial interest to cooperate fully, and assuming that the other party is also aware of this condition, then cooperation can dominate (Hill 1990; Parkhe 1993). This situation is believed to best characterize stable close working relationships between firms such as a specific subset of buyer-supplier transactions.

The shadow of the future is a multi-dimensional construct: firms can enhance the robustness of cooperation in many different ways. Three of them are: (a) by extending the time horizon of the relationship (i.e., extendedness); (b) by increasing the frequency of contact; and (c) by reducing the performance ambiguity (Heide and Miner 1992).

The extendedness of a relationship is defined as the degree to which the parties anticipate that it will continue into the future with an indeterminate end point. A relationship level of extendedness thus reflects the strength of the expectation that it will continue indeterminately. Considering a Prisoner's Dilemma iterated game, extendedness in a relationship should increase the probability of a pattern of cooperation. Thus:

Hypothesis 1a: Extendedness in a relationship positively effects the probability of cooperation between two interacting firms in a Prisoner's Dilemma context.

In this framework, for a given level of extendedness, a higher frequency of contact will lead to a greater number of expected future interactions. With extendedness controlled, high frequency of contact should predict cooperation (Axelrod 1984). In buyer-supplier relationship settings, frequency of contact can be increased in a variety of ways such as through specialization or by breaking conceptual issues into smaller pieces as suggested in conflict resolution processes (Fisher 1964).

Hypothesis 1b: Frequency of contact positively affects the probability of cooperation between two interacting firms in a Prisoner's Dilemma context.

Finally, when cooperation is based on observing the other player's actions and responding to them, performance ambiguity can make cooperation more difficult. Formal analysis confirms that if there is uncertainty about what move the other player made, it is generally more difficult (or impossible) to sustain cooperative outcomes (Bendor 1987; Kelle *et al.* 2007). Thus, increased performance ambiguity decreases the chance of cooperation (Molander 1985; Heide and Miner 1992).

Hypothesis 1c: Performance ambiguity negatively affects the possibility of cooperation between two interacting firms in a Prisoner's Dilemma context.

Numerous researches conclude that prior history in inter-firm relationship (i.e., *shadow of the past*) generates norms, specific assets and learning that increase perception of stability and thus the chance of cooperation (Gambetta 1988; Cai *et al.* 2009). Most process models of cooperation argue that, over time, parties learn from shared experiences of not only the kind of behaviour to expect from one another, but also normative routines that enhance value creation (e.g., Ring and Van de Ven 1994). This literature recognizes that in buyer-supplier relations the initial learning focuses on understanding each party's capabilities and expectations underlying the production and delivery of the product. Over time, however, as learning deepens, it reflects dimensions that are associated with stability. Summarising this perspective, we can define two different dimensions of the *shadow of the past*: (a) time horizon of previous interactions and (b) extent of norms and specific assets shared by the parties (i.e., degree of integration). These two dimensions both should predict cooperation.

Hypothesis 2a: Time horizon positively affects the probability of cooperation between two interacting firms in a Prisoner's Dilemma context.
Hypothesis 2b: Degree of integration positively affects the probability of cooperation between two interacting firms in a Prisoner's Dilemma context.

In developing the mathematical formulation, this study further adopts an interdependence perspective: the past and the future are necessarily intertwined as enablers to cooperation (Poppo *et al.* 2008). This perspective has had only marginal attention in game theory and considerable ambiguity surrounds it.

This study offers a ways in which prior history and expectations of continuity may be interconnected in encouraging cooperation addressing that, when expectations of continuity and prior history work collectively, their joint effect has a stronger impact on cooperation through the mediating effect of interorganizational trust.

Specifically, this perspective implies that the shadow of the past transforms an undersocialized relationship to one in which the history of prior relations and interactions form a social institution capable of building trust. The degree of trust built between partners increases the perception of stability and thus strengthens the expectation of continuity of the exchange making the future more predictable and reducing uncertainty.

The past represents exchanges that have developed strong social institutions that support the development of reciprocal trust and increase the possibility of cooperation; yet, without a shadow of the future, an endgame looms large on the horizon and parties deviate from the prevailing norms and routines to maximize self-interest. Similarly, even when continuity is expected, without a long history the requisite social institution is relatively weaker and underdeveloped, leading to lower level of trust and reducing the chance of cooperation (e.g., Lewicki and Buker 1996; Poppo *et al.* 2008).

Exchange characterized by a longer shadow of the past and future lead to a greater effect on cooperation. The synergistic effect of the past and the future on promoting cooperation is stronger with high level of interorganizational trust. This strong statement implies that the interorganizational trust significantly influences why or how the past and the future encourage cooperation (Gambetta 1988). Thus:

Hypothesis 3: Interorganizational trust moderates the positive collective effect of prior exchange history (shadow of the past) and the expectation of

continuity (shadow of the future) on the possibility of cooperation between two interacting firms in a Prisoner's Dilemma context.

The mathematical formulation expresses the aforementioned hypotheses.

3. The mathematical model.

In this section the general model is presented along with some basic notation. Non-cooperative game theory provides the theoretical framework for the analysis. The study considers buyer-supplier relationship setting as a non-cooperative situation because the unit under analysis is the individual participant and a cooperative behaviour can be observed only if it is in the best interest of each part singly considered. In fact, the benefits of joint cooperation are not so great that cooperation simply dominates defection for each player under any circumstances. This is evident if one considers the many decades of stable arms-length industrial relationships in which cooperation has been uncommon (Arend 2005; Heide and Miner 1992). The model exclusively considers a game played by two participants.

As mentioned above, if the players know that the game will be repeated a fixed number "*n*" of times, they will naturally adopt the opportunistic strategy in the last stage game; by backward induction, this means that they wouldn't have cooperate even in the previous periods. Things really change by considering games repeated infinitely or a finite but unknown number of times; we refer to such a game as infinitely repeated games. In this case, backward induction does not apply and future promises and threats can really influence each stage of the game. Here the problem of interest could be considered as an infinitely repeated game.

The analysis proceeds considering two different situations: *Perfect* and *Imperfect Monitoring* (Mailath and Samuelson 2006).

3.1. The Perfect Monitoring game.

In the theory of repeated games, Perfect Monitoring implies the observation of all random variables and decisions by the players after each repetition. It formalizes the insight that, if the relationship is long-lived and if the members can monitor ex-post the information signals and decisions of the other members, then the members may have an opportunity to use self-enforcing rules of behaviour that sustain efficient decision rules (Aumann 1983).

Unfortunately, the circumstances that lead to the decentralization of information and decision-making usually make perfect ex-post monitoring of information and decisions impractical. In fact, in a repeated game each player chooses his strategy in each repetition of the game as a function of some information about the course of the play of all of the previous repetitions. If this information is based on less than the complete history of all previous observations and moves of all of the players, then the game is necessarily one of Imperfect Monitoring (Radner 1986).

The study does not consider the case of Imperfect Private Monitoring *id est* the case in which quite complete information is available to one of the players while the other can get only a lacunose knowledge of the situation. In this case, asymmetric information between the players' moves affects the game (Mailath and Samuelson 2006).

Let us introduce some notations in order to describe the stage game in period *t* by its extensive form. This representation is in general smaller than its induced normal form and furthermore can be much more natural to reason about. While the Nash equilibria of an extensive form game can be found through its induced normal form, working with extensive form directly can have computational benefits. Further, the normal form representation does not incorporate any notion of sequence or time of the action of the players; instead, the extensive form makes the temporal structure explicit.

Let us denote by B the first player (i.e., the buyer) and by S the second (i.e., the supplier); we can represent the stage game in period *t* as follows in Figure 1.

Figure 1. The stage game

$$\left(u_B(C,C),u_S(C,C)\right) \quad \left(u_B(C,D),u_S(C,D)\right) \quad \left(u_B(D,C),u_S(D,C)\right) \quad \left(u_B(D,D),u_S(D,D)\right)$$
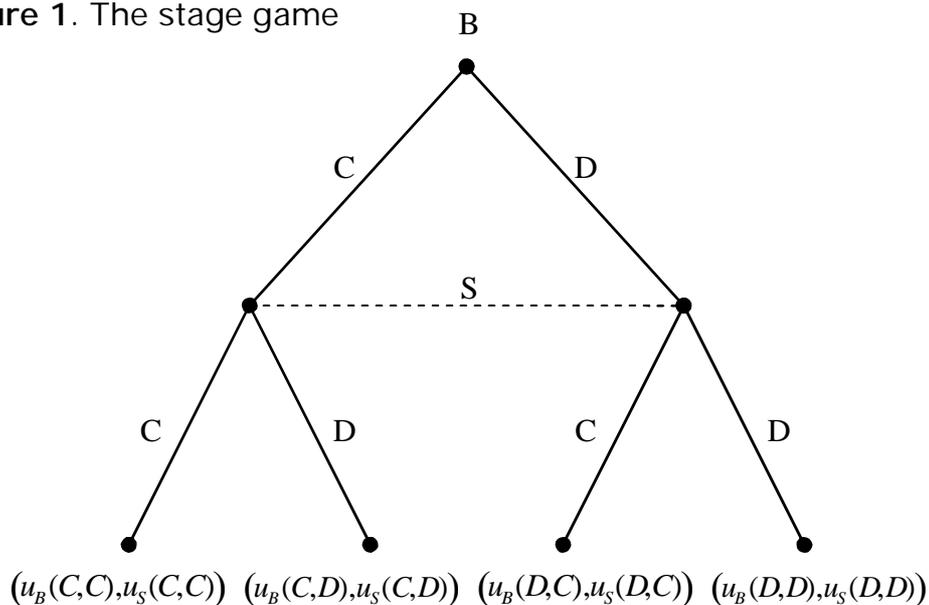
The dashed line represents an information set. This means that the analysis is considering a situation of Incomplete Information in which the supplier does not know the buyer's choice before playing or, equivalently, they are playing at the same time. We are not taking into account cases of Complete Information games where the second player is acting after the first in the sense that he actually knows what the first did before playing.

In our notation, a_B^t =C or D is the choice of player B at period t, a_S^t =C or D the choice of player S at the same period and $u_B(a_B^t, a_S^t)$, $u_S(a_B^t, a_S^t)$ are the utility function associated to the pure action profile (a_B^t, a_S^t) giving respectively the payoffs of players B and S at period t. As an example $u_B(C,D)$ expresses the payoff of player B when he cooperates and player S defects. Let us remark that the study, in seeking of simplicity, is considering the case of stationary repeated games (i.e., we suppose that the payoffs in any period are not affected by the payoffs in previous periods).

As the analysis considers an infinitely repeated game, the "real" payoff considered by each player is given not only by the utility function of the present period but by the normalized discounted sum of all payoffs. Here the functions of interest are then the global payoffs of players B and S respectively, namely

$$P_B = (1-\delta_B)\sum_{t=0}^{\infty}\delta_B^t u_B\left(a_b^t, a_s^t\right) \text{ and } P_S = (1-\delta_S)\sum_{t=0}^{\infty}\delta_S^t u_S\left(a_b^t, a_s^t\right) \text{ where } \delta_B \text{ and } \delta_S \text{ represent}$$

the discount factors for each player. To understand those δ, we observe that a measure is needed to compare present and future payoffs and that this factor is in general not the same for the buyer and the supplier. We will come back to this idea and give more details later on.

In this setting, in order to look for the existing equilibria, we have to mention the possible strategies adopted by the players. The simplest situation one can consider is the so-called *trigger strategy*; namely, each player starts by cooperating but, if ever the other player defects, then the first retaliates by defecting forever. This punishment even useful as incentive to exert effort and continue cooperating, could be considered too severe and the players would often prefer the punishment to be as lenient as possible: this is the case of the *Tit-for-Tat* strategy. Here the player starts by cooperating and thereafter chooses in round i+1 the action chosen by the other player in round i. Both strategies lead to roughly the same equilibria so that we will only consider the first one because of the linear simplicity of the related equations.

Thus, for each player the payoffs corresponding to their choice to defect in the T-period are given respectively by

$$P_B(D,T) = (1-\delta_B)\left[\sum_{t=0}^{T-1}\delta_B^t u_B(C,C) + \delta_B^T u_B(D,C) + \sum_{t=T+1}^{\infty}\delta_B^t u_B(D,D)\right]$$ [1]

$$P_S(D,T) = (1-\delta_S)\left[\sum_{t=0}^{T-1}\delta_S^t u_S(C,C) + \delta_S^T u_S(C,D) + \sum_{t=T+1}^{\infty}\delta_S^t u_S(D,D)\right]$$

Let us remark how the three addenda in the previous expressions exactly describe the dependence of the payoff on the previous periods (*shadow of the past*), the present stage game and the anticipated future interactions (*shadow of the future*).

In order to find Nash equilibria and to understand which strategy is dominant, the analysis compares those functions to the total payoffs obtained by each player if they decide to keep on cooperating:

$$P_B(C) = (1-\delta_B)\sum_{t=0}^{\infty}\delta_B^t u_B(C,C)$$ and $$P_S(C) = (1-\delta_S)\sum_{t=0}^{\infty}\delta_S^t u_S(C,C).$$

This analysis is interested in conditions under which the difference $\Delta P = P(C) - P(D,T)$ is positive for both players leading to equilibrium in cooperation. On one side, the payoff here obtained by opportunistic behaviour (pure action profile (D,C) or (C,D) for players B or S respectively) is higher than the one obtained by joint cooperation; on the other side, joint cooperation gives better results than defection of both partners. As a consequence, and for sufficiently large discount factors, cooperation can become Pareto dominant.

We will now stress the dependency of utility functions, discount factors and even the choice of the period T on the variables introduced in the theoretical framework in order to go deeper with the analysis. Starting from the two variables measuring the *shadow of the past*, the period T we are considering is given by the number of years of interaction between the two firms, while the degree of integration *DoI* (i.e., the amount of standard norms and specific assets shared by the partners) is in inverse relation to the utility functions in the cases of defection ($u_B(D,C), u_S(C,D), u(D,D)$). Concerning the *shadow of the future*, the frequency of contact between the two firms (*FoC*) is in direct relation to the utility functions in cooperation cases ($u(C,C)$ for both players) and the performance ambiguity (*PA*) is in inverse relation to them. To understand the dependency on the extendedness of the relationship (*EotR*) we need some further remarks on repeated games. As mentioned, the setting of infinitely repeated games fits our situation better than finitely repeated games' context. However, this is still a formal trick because no human interaction can pretend to be infinitely repeated. A more precise approach

consists in fixing the number N of periods; this number is the length the two players imagine for their interaction, namely the extendedness of the relationship. Anyway, following the previous analysis, when N is big enough to represent a very far horizon for both players, we will still consider facing an infinitely repeated game situation and discard all ideas and techniques arising in finitely repeated games (i.e., backward induction). In this situation, N represents exactly the extendedness of the relationship.

Finally, the analysis focuses on the discount factor δ. The discount factor measures the importance that each player attaches to future payoffs compared with present payoffs. A priori, present payoffs are always more appreciated by any player but we easily imagine that the general situation of the market and the financial and organizational stability of the firm can give rise to a sort of *patience* or *confidence* of the player (Mailath and Samuelson, 2006). Considering this, we could depict a link between this factor and the interorganizational trust concept. In fact, the importance of future payoff in the choice of the strategy made by the players could be influenced by how much they really expect that the partner (1) can be relied on to fulfil obligations, (2) will behave in a predictable manner, and (3) will act and negotiate fairly when the possibility of opportunism is present (Zaheer *et al*. 1998; Anderson and Narus 1990). In this sense, one can say that high interorganizational trust corresponds to values of the discount factor *δ* close to 1. In addition, in order to allow situations of disparity of judgments and expectations, the analysis does not consider the same discount factor for both players (Lehrer and Pauzner 1999).

To draw conclusions, let us explicitly present our condition for dominance; $\Delta P \geq 0$ becomes for each player:

$$\sum_{t=T+1}^{N} \delta_B^t [u_B(C,C) - u_B(D,D)] \geq \delta_B^T (u_B(D,C) - u_B(C,C)) \qquad [2]$$

$$\sum_{t=T+1}^{N} \delta_S^t [u_S(C,C) - u_S(D,D)] \geq \delta_S^T (u_S(C,D) - u_S(C,C))$$

The left-hand side of these equations grows with N (*EotR*), with *Foc* and *Dol*; it is instead in inverse relation to PA*.* The right-hand side is decreasing when T and Dol grow. The dependence on the interorganizational trust, here represented by the discount factor, also appears.

3.2 The Imperfect Monitoring game

Until now, the analysis has supposed that every player could observe each other's action and than that every defection can be detected and punished

(i.e., Perfect Monitoring game). However, it seems natural to consider an environment where the output is a random function of the choices of the two players. From now on, the study supposes that each player can only observe the outcome of the transaction without being able to deduce whether this is the consequence of his partner's shirking. In other words, players can only have confused information about past plays and deviations from cooperation cannot be unambiguously detected. This situation is called as Imperfect Monitoring game. The study maintains the assumption that both players observe any signals about past plays. It is excluded from the analysis the case of Imperfect Private Monitoring in which there is asymmetric information between parties so that one of the players has more precise information than the other.

As in the Perfect Monitoring game, the analysis proceeds looking for cooperation equilibria and then for incentive for players not to myopically optimize.

The stage game is here the same as in the previous setting but, at the end of each period, players only observe a public signal y. We denote by $\rho(y \,|\, (a_B, a_S))$ the probability that the signal y is realized given the action profile (a_B, a_S). To fix ideas, we state that two signals can be observed: Success (s) or Failure (f) of the transaction. The probability distribution is given by

$$\rho(s, (a_B, a_S)) = \begin{cases} p & (a_B, a_S) = (CC) \\ q & (a_B, a_S) = (CD), (DC) \\ r & (a_B, a_S) = (D, D) \end{cases}$$

with $0 < q < p < 1$ and $0 < r < p$; the fact that s signal occurs with higher probability when both firms cooperate, provides some confused information about players' actions.

We denote by $u(y, (a_B, a_S))$ the payoff received after a period where y signal is obtained as a consequence of the pure action (a_B, a_S) and the relation between ex-ante and ex-post payoffs is given by

$$u(a_B, a_S) = u(s, (a_B, a_S)) \cdot \rho(s \,|\, (a_B, a_S)) + u(f, (a_B, a_S)) \cdot \rho(f, (a_B, a_S)) \qquad [3]$$

The explicit expression of the total payoff attached to a given strategy (taking into account past and future payoffs) can be deduced from the Perfect Monitoring case but it is too heavy to manipulate.

As in the Perfect Monitoring situation, cooperation equilibria require inter-temporal incentives so that some realization of the signal must be followed by low continuation values. The analysis really infer about retaliation because

those low continuation values do not necessarily arise from a deviation but are needed to provide appropriate incentive for players to exert effort.

By imitation of the previous context, the analysis considers two main strategies: the *grim trigger* and the *forgiving strategy*. The first one consists of cooperating in the first period and switching to permanent defection as soon as a failure is detected.

If s is a sufficiently clear signal – in the sense that p approaches 1 and is much bigger than q and r, and the action (C,C) almost guarantees the signal s – the *grim trigger* strategy can represent an equilibrium. In this situation, the payoffs approach what was observed in the Perfect Monitoring setting so that, for high values of the discount factor δ, we have an equilibrium strategy. Still, an important difference appears. At the beginning of the game, players are willing to cooperate because defection leads the f signal with high probability; however, playing action (C,C) does not guarantee to get signal s. It is evident here the contrast between providing incentives and their impact on future payoffs.

The analysis considers now the *forgiving strategy*. Here, players start by cooperating and then keep cooperating after every signal s and defect after signal f. We regard as players rewarding good signals and punishing bad ones. We still have that, for high values of p, the payoffs approach the Perfect Monitoring case. Furthermore, the *forgiving strategy* gives higher payoffs than the *grim trigger*. Again, to obtain cooperation equilibrium we need a sufficiently high discount factor δ and sufficiently informative signals (i.e., $p - q$ sufficiently large). This ensures that the myopic incentive to defect is less than the continuation reward given by the more favourable probability distribution of signal s induced by (C,C) compared to (C,D), (D,C) or (D,D). Still, we emphasize that defection after f signal is no longer a punishment for the other player but just an encouragement to take due care.

Going back to the variables introduced in section 2.2, we conclude that those variables clearly appear in the expression of ex-ante payoffs and than of ex-post payoffs (cf. formula [3]). Furthermore we observe that a high performance ambiguity (PA) corresponds to values of p very close to q and r; as above, this affects the equilibrium. We also notice that the role played by the discount factor δ (that we associated with interorganizational trust) becomes even more crucial here.

4. Discussion.

The model depicted explores the influence of the exchange history (*shadow of the past*) and the anticipated interactions (*shadow of the future*) on the stability of cooperation in buyer-supplier relationships. The analysis also includes the role of interorganizational trust in facilitating the equilibria.

In developing the model, the study assumes that buyer-supplier interactions embody the structure of the repeated Prisoner's Dilemma game (Heide and Miner 1992). The analysis also presumes that the buyer and the supplier interact in discrete exchanges in which the potential for cooperation and defection is present for both parties. On one hand, the supplier can defect, for example, through late delivery or low quality supplies that cannot be readily detected or by refusing to adjust to delivery requirements and to a change in product orders. On the other hand, the buyer can defect, for example, by making late payments or by reducing the value of supplier specialized plant investments through a change in product design (Cachon and Netessine 2004). Alternating defection would incur additional costs for both parties in order to manage anticipated enforcement and would incur additional costs for the buyer for maintain safe inventory levels (Heide and Miner 1992).

As a general insight into the mathematical model, the formula [1] expressing the payoffs of the two players concurs with the theoretical framework because three addenda appear: the first one represents the exchange history (*shadow of the past*); the second one stands for the present action and the third one corresponds to the anticipated interactions (*shadow of the future*). In the same formula, interorganizational trust is also represented through the discount factor.

Considering these provisions, the study develops a buyer-supplier cooperation model in two different contexts: games with Perfect Monitoring and Imperfect Monitoring. This corresponds to different situations. In the first one, each firm has complete knowledge and full control of the behaviour of the partner so that, after each transaction, the player can correctly be aware if the other player cooperated or defected. In the second situation, only lacunose information is available so that it is difficult (or impossible) for a partner to really understand the behaviour of the other partner. Each player just knows if the last action led to a success or to a failure of the economic transaction without being able to make distinctions between cooperative behaviour or a casual or unplanned outcome.

With regards to the Perfect Monitoring context, the analysis of the condition of dominance (cf. formula [2]) shows that the stability of cooperation would be enhanced by high levels of extendedness of the relationship, frequency of contact and degree of integration (variables included in the left-hand side of the equations). The cooperation is instead in inverse relation to performance ambiguity. Further, the probability of a pattern of cooperation is positively affected by high level of the time horizon of previous interactions (on the right-hand side of the equations).

The extendedness of the relationship (or anticipated open-ended interaction) symbolizes the expectation of the partners that a relationship will continue indeterminately in the future. It is needed to point out here that, for low values of the extendedness of the relationship, all the mathematical framework fails; as a matter of fact, we have been working under the infinite repetition assumption and if the extendedness of the relationship is not big enough this represents a major distortion. At the same time, by abandoning this assumption, we can imagine the players proceeding to backward induction and considering every stage game as a separate game so that the cooperating strategies will collapse. Thus, considering the analysis of games, we should note that, although anticipated open-ended interaction does not require cooperation, it does make it possible even when neither party has altruism or concern about the other party's well-being.

The frequency of contact concept needs to be expanded. In fact, there are a variety of ways in which this variable could be increased in order to positively impact on cooperation (e.g., by tailoring the processes to a specific partner's requirement). However, the relevant interactions between buyer and supplier are those in which concrete opportunities arise from cooperation and defection. If cooperation arises only from fixed interdependencies or commitment, we would not expect frequency of contact to affect cooperation because it would be irrelevant.

Considering the mathematical expression of dominance condition, we note that the degree of integration variable appears both on the right and left side of the equation [2]. Stressing this point, we could assert that the degree of integration – mirroring the norms and routines jointly developed over time by the buyer and supplier – affects the equilibria in two different ways, namely impacting on the advantages both firms can obtain from cooperation and the detriment caused to each firm by the defection of the other.

Performance ambiguity is the variable in the model that symbolizes the difficulty of evaluating the outcomes (cooperation or defection) of a transaction. This variable is the most relevant in addressing the differences

between *Perfect Monitoring* and *Imperfect Monitoring* game. In the first context, for example, we assume that it is relatively simple to assess whether the product delivered is the best it could possibly be or the result of half-hearted efforts so that we are considering low performance ambiguity situations.

Concerning the time horizon of previous interactions (namely the length of prior relationships) between the two firms, we notice that a long history of previous interactions induces the two players to attach minor importance to the present exchange. Thus, in the choice of a general strategy the present temptation to defect is balanced by long term considerations. This appears explicitly in formula [2].

Further remarks appear with regards to the discount factor. This parameter can vary between 0 and 1. A value of 0 means that future payoffs are perceived as worthless, while a value of 1 means that future payoffs are worth as much as the current payoffs. Even in infinitely repeated games, cooperation will never emerge if the discount factor is too small, since the cumulative values of future cooperative payoffs then are too small. As the model considers the discount factor as positively linked to the degree of interorganizational trust, a high degree of trust in the partner firm should tend to increase the value of the discount factor making the equilibria more stable.

Linking the discount factor to the degree of interorganizational trust implies the consideration of "institutionalization" in trust-building processes (e.g., Berg, Dickhaut and McCabe 1995). This construct of "institutionalized trust" is closely related to the concepts of "institutional knowledge" and "institutional memory": the knowledge and the memory embedded within an organization, persisting over time, even as the individuals within the organization turnover (Rabkin 2008). Institutionalized trust between buyer and supplier make it easier for organizations to internalize the economic interests shared by the partner. It could thus motivate partners to act "rationally" in a way that provides the maximum long-term benefit to all parties (e.g., by increasing prices or limiting supply in a given market).

The considerations developed above need to be further explored with reference to the second context analyzed: the Imperfect Monitoring game.

In this case, the stage game is the same as in the previous setting but we include the public signal of success/failure in the analysis. This gives rise to a different payoffs expression that is defined as ex-post payoffs and is strongly dependent on the standard ex-ante payoffs expression (cf. formula [3]). As above, if the performance ambiguity is not too high, then the payoffs

approach as observed in the Perfect Monitoring context; thus, the formulation of the mathematical equations developed is correct only for low values of performance ambiguity. Nevertheless, an important difference appears with reference to the contrast between providing incentives and their impact on future payoffs, and then on the possibility of cooperation.

Performance ambiguity results from difficulties in measuring exchange value, increasing the likelihood of renegotiation and the resulting transaction costs (Demsetz 1988). For exchange to occur, the parties must perceive that the net value between what is received versus given is positive. Value assessments require measurement of outcome or behaviour, which is subject to errors and manipulation and so requires contractual provisions to address difficulty of monitoring. Measurement of outcome quality may be problematic because it is generally difficult to assess performance accurately before the outcome is used, which may involve a considerable delay (e.g., Sutcliffe and Zaheer 1998).

In the Imperfect Monitoring context the discount factor – linked to interorganizational trust – has an even more relevant influence in determining the equilibria. The mathematical formulation demonstrates that the higher the discount factor is, the more stable the cooperative equilibrium. In other words, as confirmed by theoretical insights from social exchange theory, trust become even more relevant in situation characterized by risk and uncertainty (Deutsch 1958; Das and Teng 2004).

Finally, the extent of the time horizon of previous interactions (or length of prior relationships) is a complex element of the model. Even if it is generally linked to pattern of cooperation between firms (Deutsch 1962), it is also possible that a firm tends to defect but it requires time for the partner to recognize it as a defection. If the firm leaves relationships once they discovered their partners were defectors, we would also see an association between length of prior relationship and cooperation in cross-sectional analysis. In this sense, we can consider the length of previous interaction to influence the precision of the signal the two players observe and therefore the stability of the cooperation equilibrium.

5. Limitations and implications for future research.

The objective of this study is to develop a mathematical model able to capture and formalize only selected features of interest about the interaction between two players (namely the buyer and the supplier). The model developed confirms that exchanges that are represented by both long

shadows of the past and future do not dissolve due to irreconcilable differences, but instead are sustained through a social institution that supports trust and cooperation because of continuity. In such relationships, parties have made various relationship-specific investments in processes and norms that support collaboration (Ring and Van de Ven 1994; Uzzi 1997). The formalism expressed by the model could be considered as a metaphor of real-life settings and could be used to derive new qualitative hypotheses and results from our assumptions by a process of deduction.

Quoting the considerations expressed by Saloner (1991), formal modeling in the management field has two main powerful attributes. Firstly, it is a methodology that is capable of creating "novel" insights, often unforeseen. This virtue stands in contrast to traditional models of boxes-and-arrows variety having no built-in capacity for going beyond a mere description of the model itself. Secondly, the formal modeling provides a common language that allows scholars to compare related results and to develop new results built on the foundations laid by earlier models. It thus provides a basis for cumulative learning.

However, the study has limitations. Some of them derive from the low possibility of assigning a predictive role to the model, mostly due to the basic assumptions of game theory perspective (i.e., rationality and profit-maximization). In addition, game theory analysis in the context of buyer-supplier cooperation has a real predictive ability only if it is supported by empirical evidence. Despite this remark, the number of relevant researches to test the predictive ability of game theory is still sparse. Future research in this direction is encouraged.

With regards to the context under analysis, some limitations emerge from the basic assumptions of our specific model.

Firstly, in the formal version of repeated Prisoner's Dilemma players do not leave the game in response to defection. From a theoretical point of view in a buyer-supplier context the firms could do so, even if some empirical evidence (Laaksonen, Jarimo and Kulmala 2009) suggest that this possibility is not so frequent. Besides, our canonical setting is that a fixed stage game is played in each of an infinite number of periods by the same two players aiming to maximize the average discounted payoffs. Actually, we are viewing the interaction of a handful of firms as a repeated game, allowing consideration of a succession of short-lived players – each of whom plays the game only once – as unique long-lived player participating to the whole repeated game. Thus, the analysis assumes that each new short-lived player can observe

signals about the partner's previous choices (Mailath and Samuelson 2006). This assumption can be misleading in some contexts.

Secondly, an apparent limitation of our model could be that, in Prisoner's Dilemma context, enforceable contracts do not exist. We recognize that this is in fact not a deviation. Although formal contracts do exist in the buyer-supplier setting, provision against many defections (i.e., late payments) are generally too costly to formally enforce the relationship (Dyer 1997). Also many aspect of cooperation – such as flexibility and creative problem solving – simply cannot be specified in formal contracts (Heide and Miner 1992).

The model has many possible extensions. As mentioned, empirical research efforts are needed in order to test the validity of our insights in concrete situations. We also suggest establishing empirical comparisons among buyer-supplier cooperative relationships in different industries.

In addition, the study could develop remarkable insights by extending the mathematical formulation in order to consider the effect of asymmetric information between the two partners. Although our model incorporates a certain degree of "disparity" – considering a different discount factor for each player – future research could be oriented towards the understanding of the Imperfect Private Monitoring context (Mailath and Samuelson 2006).

Also, the replication of the model in the case of Complete Information could be of same use. This context includes all situations where the two players do not move simultaneously (i.e., one of them is aware of the other's actions before deciding his move).

Finally, future research could expand our model by considering the dynamics of reputation and credibility. Controlled experiments could also be a useful complement to empirical studies, especially in relation to exploring individual-level perceptions of and reactions to reputation mechanisms.

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