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Abstract: Social interactions often lead to puzzling mutually-beneficial transactions. In experimental sessions, the prisoner’s dilemma and the chicken and trust games prove to be less perplexing than Nash equilibrium predicts. Moral motivations seem to complement selfish orientations, and their relative predominance in games has been observed to vary according to the individuals, their environment, and the game. This paper examines the appropriateness of Berge equilibrium to study several 2×2 game situations, notably cooperative games where mutual support yields socially beneficial outcomes. We consider the Berge behaviour rule as it complements Nash: individuals play one behaviour rule or another, depending on the game situation. We then define non-cooperative Berge equilibrium, discuss what it means to play in this fashion, and analyse why individuals may choose to do so. Finally, we discuss the relationship between Nash and Berge notions, analyse the rationale of individuals playing in a situational perspective, and establish an operational approach describing under which circumstances the same individual might play in one fashion versus another.

Keywords: Berge Equilibrium; Moral principles; Mutual support; Social Dilemmas; Situational decision making.

1. Introduction

Although experimental evidence supports the predictions of standard economic theory about the outcomes of social interactions in various competitive situations (Davis and Holt, 1993), it usually does not confirm theory in cases of cooperative situations. In two-player zero-sum games where there is a Nash equilibrium, subjects usually play according to Nash strategy (Lieberman, 1960) and even exploit the non-optimal responses of their partner in order to maximize their own benefits (Kahan and Goehring, 2007).[1] Conversely, in mixed-motive game experiments, subjects often cooperate more than they should.[2] Despite the wide disparity in the experimental results and protocols of the prisoner's dilemma (PD), meta-analysis shows that, on average, about 50% of subjects cooperate (Colman, 1995; Ledyard, 1995; Sally, 1995). Similar anomalies related to Nash predictions have been documented in studies of the chicken game (CG), where cooperation is the dominant outcome observed (Rapoport and Chammah, 1965), and in trust or investment games, where trust and reciprocity are often more significant than predicted by subgame perfection (see e.g. Berg *et al.*, 1995; Bolle, 1998).

Fischbacher *et al.* (2001) and Kurzban and House (2005) observe that in public good experiments not all subjects play in the same fashion. In their experiments, more than 50% (and up to 65%) of subjects contribute on the condition that others do the same, less than 30% are pure free riders, and the rest adopt a mix of these two behaviours. This illustrates the heterogeneity of behaviour rules: individuals have types and are likely to adapt their behaviour to their immediate environment (see also Boone *et al.*, 1999; Brandts and Schram, 2001; Keser and Winden, 2000; Fehr and Fischbacher, 2005). Experiments also show that individuals may change behaviour according to the situation of their play. For example, Zan and Hildebrandt (2005) found in a school experiment that children adopt different behaviour rules according to the type of game they are playing, with cooperative games eliciting more reciprocal interactions than competitive ones.[3] Players may also adopt different behaviour rules according to their situation in life and to the society in which they live (Henrich *et al.* 2004, 2010). For example, they observe that fairness and mutually beneficial transactions are

1 Fehr and Fischbacher (2005) also review competition experiments where Nash prediction is not valid.

2 Prisoner's dilemma, chicken games, public good and trust games are the best-documented examples of predictions of inefficient outcomes, which are not often confirmed by the empirical evidence. For surveys on the experimental evidence of other-regarding motivations and the emergence of cooperation, see Camerer (2004), Fehr and Fishbacher (2005), or Fehr and Schmidt (2006).

3 Note that there is plenty of experimental evidence of situationalism in the social psychology literature. For instance, many examples are provided by Mischel and Shoda (1995).

more prevalent in integrated societies. They speculate that such social environments decrease conformity to Nash predictions, instead encouraging subjects to be motivated by social norms reflective of moral principles[4]. Other experimental studies such as Engelmann and Normann (2010) confirm this conclusion. Specifically, these authors have found that levels of contribution in a minimum-effort game vary across countries and, more interestingly, among natives, former immigrants, and new immigrants within the same country.

Within game theory framework, moral principles are usually taken into account as other-regarding payoff transformations, a concept first discussed by Edgeworth (1893). The key to this approach is the assumption that a player's utility is a twofold function, related to both his welfare as well as the welfare of the other player(s). Individuals are assumed to care about how payoffs are allocated depending on the partner, the game situation, and how the allocation is made. Redefining the utility function in this way allows for rationalizing behaviours. It preserves the omnipotence of the Nash decision rule. Including other-regarding components in the utility function indicates that moral agents are concerned only with outcomes rather than with actions, which is a particular interpretation of moral principles. Vanberg (2008, p. 608) contends, "*moral principles, standards of fairness, justice,[...] are codes of conduct that require persons to act in fair, just, or ethical ways. They tell them not to steal, not to lie, to keep promises, etc. They are typically concerned not so much with what a person wants to achieve but with how she seeks to achieve what she wants.*" In other words, moral principles consist also in acting morally by following moral rules of conduct.[5]

We share with Eckel and Gintis (2010), two emblematic defenders of the other-regarding preferences approach, a similar view of how moral principals may intervene in the decision-making process. We posit that moral principles are governed by social norms that are situation specific. That is, every social group supports a number of standard types of social interaction, each of which includes a nexus of social practices that indicate appropriate behaviour for that type of interaction (Eckel and Gintis, 2010, p.114). However, while Eckel and Gintis argue on those grounds in defence of the other-regarding preferences approach, we claim that this is

[4] We intentionally employ the term *moral principals* instead of *other-regarding preferences*. As argued by Vanberg (2008), there is indeed a significant difference between, on the one hand, claiming that agents evaluate outcomes not only in terms of their own narrowly defined interests but also in terms of how they affect the well-being of other persons (other-regarding preferences) and, on the other hand, claiming that agents are motivated to act in accordance with ethical rules or principles such as fairness and reciprocity.

[5] Engelmann and Strobel (2004) make a related claim in their criticism of Fehr and Schmidt (1999) and Bolton and Ockenfels (2000) theories of inequity aversion. Considering experimental evidences on intentions, they argue that interactions and intensions should necessarily be co-founding factors with distributions. They conclude that these theories based uniquely on distributions should, in general, carefully clarify under which conditions they are appropriate (p. 867). So far, this has not been done, and sharper criticisms were recently directed at these theories. Among them, Binmore and Shaked (2010) criticized the *ad hoc* character of adding other-regarding components in utility functions.

precisely the reason why payoff transformation is an insufficient method by which to include moral principals in games. If we grant that individuals may be other-regarding, our point is that purely self-oriented individuals may *also* adopt social practices reflecting moral principles. Said differently, although other-regarding preferences may be part of the puzzle, we are interested in defining a truly behavioural theory that questions behaviour rules and social practices rather than a theory based on somewhat *ad hoc* motivational factors loosely integrated into utility functions (Güth and Kliemt, 2010, p. 48).

The purpose of this paper is to examine whether complementary behaviour rules and equilibrium concepts may be intertwined with the Nash rule, leaving utility functions unchanged. In line with Pruit and Kimmel (1977), we allow individuals the capacity to adapt their behaviour rules to the situation.[6] In some games, such as zero-sum situations where self-oriented maximization is sufficient to drive action, the Nash rule tends to be adopted. In others, such as games involving collective action, complementary rules that encompass moral principles may drive actions. This situational perspective has analogies with the rule-following behaviour approach proposed by Vanberg (2008) and is more generally inspired by the situational approach[7] in social psychology, according to which, personality is construed not as a generalized or a contextual tendency but as a set of "*If ...then*" contingencies that spawn behaviours of the "*If situation X, then behaviour Y*" type (Mischel and Shoda, 1995, 1999).

We focus on how to play conventional games such as PD, CG, and trust games and examine one possible complementary behaviour rule to the Nash rule and its associated equilibrium concept. Our behavioural hypothesis is that, in many interactive situations, choice requires that each player incorporate the welfare of the other as a key element of his or her own *reasoning*. Independently from their preferences and utility functions, individuals may choose to play this way if it is in their interest to adopt this rule-following behaviour. As Wilson (2010) suggests, individuals may be conditioned by society to unconsciously apply different rules of behaviour according to the contextual cues of their current situation. We posit that in some game situations, individuals care about the welfare of others *if* they believe that others will reciprocate. This is a form of mutual support. Real life examples are numerous and are related to the notion of *savoir vivre,* a set of rules of conduct such as respect for

6 Note that authors considering other-regarding payoff transformation also assume that moral principles vary according to the game situations. They consider that other-regarding components in the utility functions of players vary according to the game situation. However as argued by Binmore and Shaked (2010), these authors do not say anything about how this parametrization of utility functions is ruled, nor the reason why it should change from one situation to another.

7 A good literature review of the situational approach in social psychology is provided by Reis (2008).

others, politeness, or courtesy. *Savoir vivre*, however, does not mean that cooperating individuals are better people (i.e. more altruistic or fair) than non-cooperating individuals. As suggested by Engelmann and Strobel (2004), this may only suggest that they are better economists, meaning that respecting these social practices more effectively enables them to reach social efficiency. As an illustration, when subjects in the trust game end up at ($25,$15) and not at ($10,$10) or ($40,$0), it is because players are in agreement that this interaction prescribes a rule of reciprocity that culminates in a Pareto improvement (Wilson, 2010, p.81).

To examine mutual support in social interactions, we consider an old concept known as the Berge equilibrium (Berge, 1957). We find this concept appropriate for two main reasons. First and most importantly, mutual support is a possible interpretation of Berge equilibrium. Playing under Berge rules, agents choose the strategy that maximizes the welfare of others, expecting that others will reciprocate. At a Berge equilibrium, all players choose actions that maximize the welfare of others. This is a mutual support equilibrium. Secondly, Berge equilibrium is a theoretically suitable concept in combination with Nash equilibrium. A key assumption of this paper is that individuals have internalized social norms that tell them how to play various game situations. The underlying hypothesis is that, according to the situation, an individual may well play according to one strategy or the other. Formally speaking, the definition of a consistent theory combining several equilibrium concepts requires compatibility of these concepts. The Berge behaviour rule and Berge equilibrium are good complements for Nash: Berge equilibrium is defined in a non-cooperative game-theoretical setting but is not a refinement of Nash. Berge explains some cooperative situations, while Nash explains many competitive ones; additionally, Berge shares several common theoretical properties with Nash, making it particularly appropriate and easy to handle from a situational game perspective.

The principal achievement of this paper is to provide the first step toward a consistent, formalized behavioural theory that accounts for individuals following different behaviour rules depending upon the situation. We define and interpret Berge behaviour rule and equilibrium as complementary to Nash rule and equilibrium and we establish an operational method explaining when, given different situations, the same individual applies one rule or the other.

The paper is organized as follows. Section 2 introduces non-cooperative Berge equilibrium, in which we discuss this concept from a historical perspective and propose a definition. We then interpret the Berge behaviour rule and discuss the rational of mutual support. Section 3 focuses on decision-making and analyses the relations between Berge and

Nash equilibria. Here also, the existence conditions for Berge equilibrium are examined and a systematic and simple method to bridge the two equilibrium notions is proposed. Finally, we study the rationales of agents and examine when players adopt one behaviour rule vs. other. The last section offers some conclusions.

2. Non-cooperative Berge equilibrium

It was Harsanyi (1966) who made Nash equilibrium and its refinements the canonical concept in game theory**.** Nash equilibrium became the *"test"* against which all solutions for any game must be measured, and as stressed by Rasmussen (2007, p. 27), *"Nash equilibrium is so widely accepted that the reader can assume that if a model does not specify which equilibrium concept is being used, it is Nash equilibrium"***.** Reasons behind this success are manifold: it constitutes the minimal stability concept, which can be defined in a non-cooperative game setting; additionally, it is a particularly appropriate method by which to study competition situations and admits only a few competitors that are not refinements. However, one may argue that it is not sufficient as such to capture the logic of collective action that results from other-regarding motivations. To address this, we reintroduce and present non-cooperative Berge equilibrium as a complementary notion to Nash equilibrium.

2.1 The history of a little-known concept

After the first conceptualizations of Berge equilibrium, some fifty years lapsed before its existence conditions were to be explicitly articulated. The initial intuition of the concept came from the mathematician Claude Berge, who defined coalitional equilibria[8] in the "*general theory on n-player games*," published in 1957.[9]

Berge's book made only a minor ripple in the academic pool, and is rarely cited.[10] However, it provides an impressive assessment of the state of research in 1950s' game theory, as well as a diagnosis and an interesting development of new results. From a contemporary perspective, two specificities of the book are particularly striking. First, the "*general theory of n-player games*" remains current; any up-to-date textbook striving to provide a general theory

[8] Refer to Laraki (2009) for the properties of the Berge coalitional equilibrium.

[9] The book was published in 1957 when Claude Berge was visiting professor at the Institute of Advanced Study at Princeton (Toft, 2006). It is in this book that the concept of the topological game appears for the first time. From 1951 to 1957 Berge works on game theory and publishes essentially in French journals. From 1957, his work focuses on graph theory. Berge introduces the notion of hypergraph, and it is as a specialist in graph theory and operational research that he officiates at the editorial board of the international Journal of Game Theory from the creation of the journal in 1971.

[10] Among the few citations to his work, most are to the generalization of the Zermelo-Morgenstern's theorem in the first chapter, e.g. Aumann (1960). Note also that most references are in the area of applied mathematics, not economics.

of games includes similar content. In five chapters, Berge's book covers the major themes that have been the motivation for game-theoretic research in the last 50 years: games with complete information (ch. 1), topological games (ch. 2), games with incomplete information (ch. 3), convex games (ch. 4), and coalitional games (ch. 5). Second, the book is an impressive contribution to the literature in its provision of a compilation of theorems related to n-player games. Though some were new and others were already known, Berge provided alternative demonstrations of them, including, for example, the theorem on unicity, the existence of the Shapley value, and the Von-Neumann Morgenstern solution.

In our view, there are four major reasons for the lack of impact made by Berge's book. First, it was published in French, which limits its diffusion at the international level. Second, it is not aimed at economists: Berge was first and foremost a mathematician and wrote his book from this perspective. There are no examples or applications of his results, which likely disappointed 1950s' social scientists who were not well-acquainted with mathematical techniques. Third, Berge defines strategies and equilibria using graph theory and topology. Again, social scientists may not have been fluent in this mix of mathematical techniques. Fourth, in 1957, Luce and Raiffa published their seminal work, which provides a more pedagogical contribution and contains more accessible examples and applications.

Turning to reviews of Berge's work, we find two unique articles. The first is by the mathematician John Peck in 1960, and the second by the economist Martin Shubik in 1961. Peck criticizes Berge's work for its misleading claims of simplicity: *"In his preface, the author states that he has taken care to write for a reader who knows no more than the elements of algebra and set theory, and a little topology for chapters 2 and 4. He might have added that a mathematical maturity is also required, for this is not an easy book for a beginner. With a multiplicity of new notions, some defined on almost every page, and some (e.g. cooperative) perhaps not at all, an index of terminology is sorely missed"* (p. 348). Shubik echoes this sentiment, stating *"the argument is presented in a highly abstract manner and no consideration is given to applications to economics"* (p. 821).

Though Berge's book was translated into Russian in 1961, the first Russian reference to Berge equilibrium came in 1985 from Zhukovskii, a mathematician who reformulated the Berge coalitional equilibrium from an individualistic perspective and named it the Berge equilibrium. Zhukovskii's paper does not focus exclusively on Berge equilibrium: it is some 90 pages long and discusses the design of a research program on differential games. In it, the author highlights 10 topics, the 10th being Berge equilibrium. According to Zhukovskii, this equilibrium notion should be introduced into differential games because it exhibits several convenient properties of Nash equilibrium while excluding some of its disadvantages. Though this observation was not useful in justifying the use of one equilibrium notion over another, it was enough for Russian mathematicians to begin studying the conditions for existence and the properties of Berge equilibrium in differential games.[11]

It was not until 2004 that Abalo and Kostreva (2004, 2005) proposed an existence theorem of pure strategy Berge equilibrium in normal form games. They elaborated their theorem on the basis of work done by Radjef (1988), a former PhD student of Zukovskii who defined an existence theorem of Berge equilibrium in differential games. Nessah *et al.* (2007) and Larbani and Nessah (2008) then proposed a new existence theorem, providing analytical validity to Berge equilibrium and demonstrating that the conditions in Abalo and Kostreva (2004, 2005) are not sufficient to prove the existence of a pure-strategy Berge equilibrium. In a recent related paper, Colman *et al.* (2011) explore some properties of the equilibrium and locate Berge equilibrium in relation to existing game theory. Interpreting mutual support as a product of altruistic motivations, they present examples in detail, including potential applications.

2.2 Definition and interpretation

Consider the game G = $(N,(S_i)_{i\in N},(U_i)_{i\in N})$, where N denotes the set of players, S_i the non-empty strategy set of player i, and U_i his utility function. U_i is defined on S = $\prod_{i\in N} S_i$, where S is the set of all strategy profiles and s_{-i} is the strategy profile $(s_1,...,s_{i-1},s_{i+1},...) \in S_{-i} = \prod_{j\neq i} S_j$.[12] We start with the definition of Nash equilibrium and proceed to the definition of Berge equilibrium.

Definition 1. A feasible strategy profile $s^* \in S$ is said to be a Nash equilibrium if, for any player $i \in N$, and any $s_i \in S_i$, we have :

$$U_i(s_i, s^*_{-i}) \leq U_i(s^*)$$

[11] A synthesis of those works is provided in Zukovskii and Tchikri (1994).

[12] In game theory, utility functions usually reflect overall preferences of agents and therefore encapsulate preferences over outcomes such as equity concerns about distribution of rewards. In the current paper, the reader may either consider this usual definition, i.e. preferences over actions not being accounted for in the payoff valuation, or, as in experimental gaming, consider that utility reflects a reward in the form of a fixed amount of money and is associated with a choice absent of any other-regarding preferences.

The Nash equilibrium is immune to unilateral deviations: player i has no incentive to deviate from his Nash strategy given that other players also do not deviate from their Nash strategy.

Definition 2 (Zhukovskii, 1985). A feasible strategy profile $s^* \in S$ is said to be a Berge equilibrium if, for any player $i \in N$, and any $s_{-i} \in S_{-i}$, we have:

$$U_i(s_i^*, s_{-i}) \leq U_i(s^*) \tag{1}$$

Playing Berge equilibrium strategy, i yields his highest utility when others also play according to Berge strategy. Unlike Nash equilibrium, Berge equilibrium is not immune to unilateral deviations. Player i is penalized if other players deviate from the Berge strategy, but the equilibrium notion does not say anything about whether player i might improve his welfare by deviating. In this sense, Berge equilibrium is not a standard game solution as defined by non-cooperative game theory in that it is not meant to be immune to unilateral or collective deviations. In contrast to Nash equilibrium, where each player maximizes his utility over his own strategy set, playing a Berge equilibrium strategy consists of maximizing over the set of strategies of the other players.

We believe this equilibrium concept deserves particular attention because of the reciprocal dimension it embeds.[13] To shed light on this, we start with an illustration. Consider a simple PD. As usual, players may either cooperate (C) or defect (D), resulting in four possible outcomes: mutual cooperation (CC), unilateral exploitation (CD or DC), and mutual defection (DD). The game is illustrated by the following matrix:

		Player 2	
		C	D
Player 1	C	R,R	S,T
	D	T,S	P,P

where R equals the reward for mutual cooperation; P is the punishment for mutual defection; T is the temptation to cheat the opponent; and S is the payoff of the person who is exploited.

[13] Note that adding other regarding components in the utility function of Nash-players may lead to similar game outcomes as the one described by Berge equilibria. Adding other-regarding components may actually lead to any game outcomes depending on the parametrization of the components. As argued in the introduction of the paper, our approach has little in common with the other-regarding preference approach and may only be seen complementarily. What we claim to capture using this equilibrium concept is the reciprocal behaviour to morally care about others in well-identified social interactions.

For a strict dilemma situation, we set T > R > P > S. Strategy D is a dominant strategy and outcome (D,D) is the pure-strategy Nash equilibrium of the game.

Let us now look at the Berge equilibrium of this game. Observe that outcome (C,C) fulfils definition 2:

$$U_1(C,C) > U_1(C,D) \text{ and } U_2(C,C) > U_2(D,C)$$

This is not true for (D,D):

$$U_1(D,D) < U_1(D,C) \text{ and } U_2(D,D) < U_2(C,D)$$

We deduce that mutual cooperation (C,C) is a pure-strategy Berge equilibrium and (D,D) is not. The cooperative outcome in the PD is yielded when players follow a Berge behavior rule.

For $i \in N$, let α_i denote player i's security level, that is, the amount $\max_{s_i \in S_i} \min_{s_{-i} \in S_{-i}} U_i(s_i, s_{-i})$ that he can guarantee to himself, independent of what the others players do. We say that issue s^* is individually rational if it yields each player at least his own security level:

$$\alpha_i \leq U_i(s^*) \quad i \in N,\ s_{-i} \in S_{-i}. \qquad (2)$$

Considering the PD, we have:

$$\alpha_1 = \max\{\min_{s_2} U_1(C,s_2), \min_{s_2} U_1(D,s_2)\} = \max\ \{S,P\} = P < R \text{ and } \alpha_2 = P < R,$$

and we conclude that the strategy profile (C,C) is individually rational. Considering now a simple CG and using similar notations, the payoff order is T > R > S > P. Besides the two pure-strategy Nash equilibria, (C,C) is the only pure strategy Berge equilibrium, and this outcome is individually rational.

In order to understand how paradoxes are disentangled, we scrutinize the logic underlying this equilibrium concept and the meanings of the associated behaviour rule. The main question that arises is: why would other players consent to playing Berge strategy when player i does so? Egoistic utility maximization predicts unilateral deviation, and playing in a Berge fashion can be interpreted in two ways:

The first interpretation is related to altruism and finds analogies with solidarity as defined first by Ibn Khadun (1378), then Durkheim (1893), and subsequently many others.[14] Members of a family, for example a husband and a wife, may put the utility of their partner before their own.[15] Even in a winner-loser zero-sum game, this altruistic type of individual

[14] Ibn Khaldun conception of solidarity (*"asabiyah"*) is dynastic and occurs within small groups such as tribes. For Durkheim, solidarity is a sense of likeness that would favor a common consciousness maintained by social pressure and conformity.

[15] A treatment of solidarity related to our approach is performed in Arnsperger and Varoufakis (2003).

attempts to lose so that the other may win. In this situation, maximization of another's utility translates to minimization of individual utility. In other game situations, such as PD or CG, altruistic individuals naturally cooperate, rather than compete. Indeed, cooperation is the dominant strategy to maximize the utility of the other. With mutual cooperation, both players end up in a better situation. The principal limit of this perspective is its narrow domain of application. Realistically, pure altruism is restricted to a few specific environments, such as the family circle, wherein the other is perceived as more valuable than oneself.

The second interpretation, mutual support, is a form of reciprocity and is related to introspection. Consider a player j who can either play his Berge strategy or not, given that the N-1 other players play their Berge strategy. According to definition 2, we have**:**

$$U_i(s_i^*, s_{-i-j}^*, s_j^*) \geq U_i(s_i^*, s_{-i-j}^*, s_j) \ \forall i \in N, \ \forall s_j \in S_j.$$

When playing his Berge strategy, player j maximizes the payoff of i. This is true for any $i \in N$ and, in fact, player j maximizes the utility of all other players. When playing Berge strategies reciprocally, the other players maximize the utility of j and of all their partners if they also play Berge strategies. In several game situations, everyone improves his utility: this represents mutual support and is unrelated to solidarity or dynasties. Mutual support is often observed between strangers, and individuals generally play this way because it conforms to a set of rules of conduct that serve the common interest. For Sen (1987), when players face situations such as the PD, they may adopt reciprocal behaviour because they understand that success in such situations is the result of mutual interdependence. Even if players do not encapsulate others players' goals, acknowledging interdependence may lead to adopting behaviour rules that realise the goals of the other group members. According to this logic, the Berge equilibrium should not be regarded as a solution concept opposed to the Nash equilibrium. Rather, it should be regarded as a complementary concept insofar as it applies to situations where agents believe that others can adopt the same type of reasoning as themselves.

To address the question of how mutual support can be sustainable in the face of deviations over time, we build on the work of cognitive psychologists. According to Anderson (1991, p. 428), "*The mind has the structure it has because the world has the structure it has*." In other words, the mind has evolved certain structures because those structures permitted our early ancestors to solve critical problems effectively and efficiently. More specifically, the rules of conduct underlying this mutual support are related to Kropotkin's mutual aid principle, or the predisposition to help one another.[16] In "*Mutual Aid: A factor of evolution*"[17] published in 1902, Kropotkin offers a scientific explanation of mutual aid, elaborating on the work of Darwin (1859) and responding to social Darwinist Thomas Huxley (1888). Kropotkin claims that the codification and interpretation of social relationships under the prism of Darwin's "*struggle for life*" theory is a misunderstanding. His view is that mutual aid plays a significant role in the evolution of society, far more than is posited in the "*social struggle for life*" theory.[18] Considering historic events, Kropotkin observes that when faced by the scarcity of a resource, overpopulation does not necessarily lead to conflict but may, in fact, lead to migration. In his view, life as organized by society is the most adequate response to the struggle for survival in an inhospitable world. Hence, he contrasts survival against one another within a group to group survival against the world. Life in a society is viewed as providing mutual protection, enabling the conservation and prosperity of the species.[19] Although accepting the importance of the individual in the community, Kropotkin claims that social progress cannot arise from individualistic competition. Instead, it is the result of the mutual capacity to support one another when problems involve collective action.[20] In this perspective, mutual support and egoism coexist, with individuals playing one behaviour rule or the other according to the problem with which they are confronted. Singer (1993) supports this perspective, arguing that consideration of others' interests has long been a necessary part of human experience. By playing mutual support in some situations, total utility is maximized; in these situations, individual utility maximization becomes corollary.[21] Self-interest can obviously conflict with utilitarianism and lead to collective action paradoxes. However, as suggested by Singer (1993, p. 143) in a reference to the Golden rule: "*Given*

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16 Note that Kropotkin in the *"Anarchist Moral"* published in 1891 employs the terms solidarity and mutual aid indiscriminately. He then abandons the term solidarity which he judges to be too focused to include mutual aid motivated only by the mutual interest in helping one another.

17 Although mutual aid did not attract much attention from the biological and economics literature, authors such as Fong *et al.* (2006) and Foster and Xavier (2007) recommend further study of Kropotkin's work to better understand the foundations of cooperation.

18 Dugger (1984, p. 973) notes that the book *"was written especially to show that a full theory of evolution must include the workings of cooperation for survival as well as the standard competition for survival"*. This statement was notably defended by Gould (1988).

19 Focusing on Siberian tribes, Polynesian islanders, medieval corporations, as well as nascent industrialized society, he demonstrates the presence of mutual support in the development of human society. He argues in particular that since Stone Age man, mutual aid has played a key role in survival and progress, leading humans to live first in clans and then in tribes. Through hunting, collective defense and common territorial property, human beings developed social institutions that served as foundations for social progress. Society successively enlarged, with villages, cities, and countries, ruled by stringent social institutions enabling collective action and limiting individualism.

20 Refer also to the analysis of Kropotkin's work in Glassman (2000) and Caparros *et al.* (2010).

21 A large literature is devoted to the validity of this corollary with notable criticisms of utilitarianism based on ethical considerations around equity, average versus total utility paradoxes, and the repugnant conclusion (Parfit, 1984; Rachels, 2001).

others have senses, and like us, feel suffering and pain […] our reason should tell us that if we would not like to be made to suffer, neither will they." This is reminiscent of Axelrod's tit-for-tat strategy and, referencing Binmore's (2007) illustration of an anonymous vampire bat's strategy to survive, mutual support can be considered as one of the internalized social behaviours used in the repeated game of life to ensure success in some situations.[22]

Returning to Berge equilibrium and recognizing that mutual support translates into playing Berge strategy and egoistic competition into playing Nash strategy, we next examine how the game may be played and in which specific situations.

3. Nash versus Berge behaviour rule

3.1 Two theoretically related equilibrium concepts

In studying Nash and Berge equilibria in well-known two-player games, we acknowledge that the relationship between these two equilibrium concepts is not straightforward. In some games, there is no Nash equilibrium but a unique Berge equilibrium (e.g. the taxation game), and in others, it is the reverse. There are games with a multiplicity of Nash equilibria but a unique Berge equilibrium (e.g. the CG), and others with multiple Berge equilibria but a single Nash equilibrium. There are also games where Nash and Berge equilibria coincide, as is the case with the battle of the sexes, as well as games where they do not (e.g. PD).

Larbani and Nessah (2008) study conditions in which the two equilibria coincide. To complement this analysis and to better understand how to bridge the two concepts, we study the existence condition of Berge equilibrium and propose a simple rule illustrating the relationship between the two.

First, we note that the existence conditions for Nash equilibrium and Berge equilibrium are related. Focusing on two player games,[23] N= $\{1,2\}$, and denoting S_i as the set of strategies for player i, we have:

Existence result. *A 2×2 game has at least one Berge equilibrium if:*

- *the strategy sets S_1 and S_2 are non-empty, convex and compact,*

[22] Note that traditionally in non cooperative games, the study of reciprocity is limited to sequential (e.g. sequential prisoner's dilemma and trust game) and to repeated games (e.g. tit for tat in the repeated prisoner's dilemma). Applying Berge equilibrium translates in assuming that players exhibit reciprocal behaviours in static games (e.g. one shot prisoner's dilemma). This questions the true nature of reciprocity. Berge equilibrium could contribute the establishment of a taxonomy.

[23] In the case of n-player games, additional conditions are necessary to ensure the existence of Berge equilibrium. For more details, see Nessah *et al.* (2007).

- *the utility functions* U_1 *and* U_2 *are continuous on S,*

- *the function* U_1 *is quasiconcave on* $S_2, \forall\ s_1 \in S_1$, *and the function* U_2 *is quasiconcave on* $S_1, \forall\ s_2 \in S_2$.

Proof. Let C: $S \to S$ be a multi-valued mapping such that $C(s_1, s_2) = C_1(s_1, s_2) \times C_2(s_1, s_2)$ where:

$$C_1(s_1, S_2) = \left\{ s_1^* \in S_1 \,/\, U_2(s_1^*, s_2) = \mathrm{Max}_{s_1 \in S_1} U_1(s_1, s_2) \right\} \subset S_1$$

$$C_2(s_1, S_2) = \left\{ s_2^* \in S_2 \,/\, U_2(s_1, s_2^*) = \mathrm{Max}_{s_2 \in S_2} U_1(s_1, S_2) \right\} \subset S_2 .$$

By compactness of S_i and continuity of U_i, i = 1, 2, we can easily show that C has non-empty, compact values and a closed graph. Furthermore, it also has convex values whenever U_i, i = 1, 2, is quasiconcave. By Fan-Glicksberg's fixed point theorem, the multivalued mapping C has a fixed point and thus, the game has a pure Berge equilibrium. #

Note that the first two conditions of this existence result are common to the Nash equilibrium existence conditions. The only difference between the two equilibria is that the function $U_i(s_1, s_2)$ must be quasi-concave in s_i for all given s_j in the Nash equilibrium, and quasi-concave in s_j for all given s_i in the Berge equilibrium. Fan-Glicksberg's fixed point theorem is sufficient to ensure the existence condition of Nash equilibrium when the objective functions are continuous in their domains and quasiconcave in their own strategy. It is also sufficient to ensure the existence condition of Berge equilibrium when the objective functions are continuous in their own domains but quasiconcave in the strategy of the other. The result is that both equilibria are fixed points in which Nash equilibrium is immune to deviation from individual action and Berge equilibrium is immune to deviation from the action of the other.

Below, we deduce an explicit relation between these two equilibria. Let us associate game $\overline{G} = (N = \{1,2\}, S_1, S_2, V_1, V_2)$ with game $G = (N = \{1,2\}, S_1, S_2, U_1, U_2)$, with $V_1 = U_2$ and $V_2 = U_1$.

Computation method. A strategy profile $s^* \in S$ *is a Nash equilibrium of game G if and only if s* is a Berge equilibrium of game* $\overline{G}$.

Proof. Consider game G and let $s^* = (s_1^*, s_2^*)$ be a Nash equilibrium of G. By definition, we have:

$$\forall\ s_1 \in S_1 \quad U_1(s_1, s_2^*) \leq U_1(s_1^*, s_2^*)$$

$$\forall\ s_2 \in S_2 \quad U_2(s_1^*, s_2) \leq U_2(s_1^*, s_2^*)\ .$$

Given $V_1 = U_2$ and $V_2 = U_1$,

$$\forall\ s_1 \in S_1 \quad V_2(s_1, s_2^*) \leq V_2(s_1^*, s_2^*)$$

$$\forall\ s_2 \in S_2 \quad V_1(s_1^*, s_2) \leq V_1(s_1^*, s_2^*)\ .$$

Thus, s* is a Berge equilibrium, and the reciprocal may be proved in a similar way . #

In other words, the set of Berge equilibrium in the 2x2 game coincides with the set of Nash equilibria in the homothetic game in which the utility of the two players is permutated. To identify the Berge equilibrium of a game, it suffices to permute the utility of players – as if they were assuming their partner's joys and sorrows – and to identify the Nash equilibrium resulting from this new situation.

This result generalizes only partially to the N-player case. If $s^* \in S$ is a Berge equilibrium of game G, this is the common Nash equilibrium of the set of games obtained by the permutation of players' utilities (see Colman *et al*., 2011). However, the reverse is not true, making our computation method a necessary, but not sufficient, condition to obtain a Berge equilibrium by permutation in N-player games.[24]

Let us illustrate the computation method in a simple taxation game (where there is no Nash equilibrium). Let player 1 be the state and player 2 be a firm. The state can either tax (denoted T) or not tax (denoted NT) while the firm can either invest (denoted I) or not invest (denoted NI). The matrix of the game is the following:

		Player 2	
		NI	I
Player 1	T	0,1	3,0
	NT	1,2	2,3

We have $U_1(NT, I) > U_1(NT, NI)$ and $U_2(NT, I) > U_2(T, I)$, and there is a unique Berge equilibrium given by (NT,I). Permuting utilities, we obtain the following modified game:

[24] Note that it is possible to establish a relationship between the two equilibrium concepts in the N-player case. We know that at a Berge equilibrium, the strategy of player i $\in$ N is determined by the N-$\{i\}$ players. We can assume that the N-$\{i\}$ players is a single player. As established by theorem 3 in Colman *et al*. (2011), the Berge equilibrium of an N-player game can be determined by finding the Nash equilibrium of its N two-player component games.

			Player 2	
		NI		I
Player 1	T	1,0		0,3
	NT	2,1		3,2

which admits a unique Nash equilibrium given by (NT,I). Our computation method shows that this is also the unique Berge equilibrium of the initial game, and this corresponds exactly to the previous result.

It follows that analysing the choices of agents who mutually support each other is technically equivalent to analysing the choices of agents acting egoistically in a modified game where utilities are permutated. We deduce that Berge equilibrium admits similar properties to Nash equilibrium in the sense that, according to the payoff structure, equilibrium may or may not exist, and it may be unique or multiple. Three corollaries apply: (1) if in the modified game, the set of Nash equilibrium is empty, there is no Berge equilibrium in the initial game; (2) if there are several Nash equilibria in the modified game, there are also several Berge equilibria in the initial game; (3) if the modified game coincides with the initial game, Nash and Berge equilibria also coincide.

3.2 The situational perspective

In assuming that individual decision-making is governed by distinct behaviour rules, the most important question is which behaviour rule will dominate in a given situation. This question is not new: it has fed the social psychology trait-situation debate for several decades.[25] Many have criticized the situational approach for its lack of conceptualization and failure to address an operational theory of the mind. For example, Kenny *et al.* (2001, p. 129) criticize the fact that "*there is no universally accepted scheme for understanding what is meant by situation. It does not even appear that there are major competing schemes, and all too often the situation is undefined*." Reis (2008) proposes a taxonomy characterizing various situations. He reviews the several attempts made to formulate a situation-based theory of personality and, drawing on Interdependence Theory, derives a taxonomy comprising six dimensions of outcome interdependence: (1) the extent to which individual outcomes depend

[25] For an overview of the long debate on personality and situation, refer to Van Mechelen and De Raad (1999).

on the actions of others; (2) whether individuals have mutual or asymmetric power over one another's outcomes; (3) whether individual outcomes correspond or conflict with those of others; (4) whether partners need to coordinate their activities to produce satisfactory outcomes, or whether the actions of either partner are sufficient to determine the other's outcomes; (5) the temporal structure of the situation: whether it involves long term interaction; and (6) information certainty: whether partners have the necessary information to make good decisions, or whether there is uncertainty about the future.

In contrast to most situational approaches in social psychology, the context we examine is relatively simple given that we consider only two behaviour rules and focus on simple 2×2 game situations. Using the taxonomy described above, we conjecture that Berge equilibrium is especially pertinent when individuals have mutual power over one another's outcomes, when outcomes do not correspond, when there is a need for partners to coordinate to produce the desired outcome, when the situation is replicated, and when all necessary information is available. Although it would be interesting to test these hypotheses experimentally, in the following pages we limit our discussion to the development of an operational approach to determine which rule is preferred and when.

We consider that an individual plays according to Berge rule and expects that the other player does the same, with the knowledge that this conduct rule will achieve the best outcome. In other words, we posit that whatever behaviour rule is chosen, agents are motivated by individual utility maximisation. While they may play according to either a self-oriented or a mutually supportive rule of conduct, in all cases they are motivated by success.

The Berge behaviour rule and equilibrium give peculiar results when studying zero sum game type situations. To see this, consider a two player zero sum game where U_1 is the utility function of player 1, and U_2 is the loss function of player 2, $U_2 = -U_1$. We know that (s_1^*,s_2^*) is a Berge equilibrium if:

$$\forall\ s_2 \in S_2,\ U_1(s_1^*,s_2) \le U_1(s_1^*,s_2^*),$$

$$\forall\ s_1 \in S_1,\ U_2(s_1,s_2^*) \le U_2(s_1^*,s_2^*).$$

As $U_2 = -U_1$, player 1 obtains the maximum payoff if 2 agrees to play a Berge strategy s_2^* which consists of maximizing his loss (*i.e.*, $\max_{s_2} U_1(s_1^*,s_2) = \max_{s_2}[-U_2(s_1^*,s_2)]$). Similarly, player 2 obtains the lowest loss if 1 agrees to play a Berge strategy s_1^* so as to minimize his utility (*i.e.*, $\min_{s_1} U_2(s_1,s_2^*) = \max_{s_1}[-U_1(s_1,s_2^*)]$). This is sacrificial behaviour and is not compatible with utility maximisation. More generally, competition situations such as competitive games and Bertrand or Cournot duopolies, do not fit with mutual support, which involves mutually exclusive goal attainment. In such cases, individuals have incentives to adopt Nash-type behaviour. On the other hand, mutual support and the Berge rule seem appropriate in cooperation-type situations where agents need to coordinate their activities to produce satisfactory outcomes. Yet in all cases, as is suggested by experimental evidence, there is no rule of thumb: the environment within which players are interacting significantly affects the behaviour rule they choose to follow. In particular, the perception of the other's intent is a critical determinant of the choices made in most bargaining and social dilemma games (Messick and Brewer, 1983). Individuals in close relationships respond differently to conflicts of interest depending on whether they perceive their partners to be open minded and responsive, or self-serving and hostile (Murray *et al.*, 2006). Finally, individuals are much more likely to approach a stranger who they expect to like them than one that they think may not like them (Berscheid and Walster, 1978). A key component in the choice of how to act is related to expectations about how partners will react.

3.3. Situations and dispositions: an operational approach

Gauthier (1986) provided the first analysis of games from a situational perspective. Gauthier's approach is especially relevant in our case since it negates the need for an association between behaviour rules and situations. Gauthier's disposition approach tells us whether a given game should be played using a Nash or Berge rule.[26] Gauthier assumes that individuals choose their dispositions prior to an interaction. Dispositions are defined as behaviour rules and may change depending on the situation. Focusing on the PD, Gauthier also assumes that individuals can adopt one of two dispositions: (i) *"straightforward maximization,"* a behaviour rule according to which they *seek to maximize their utility given the strategies of those with whom they interact*; or (ii) *"constrained maximization,"* a behaviour rule according to which they *"seek in some situations to maximize their utility, given not the strategies but the utilities of those with whom they interact"* (p. 167). Given these possibilities, Gauthier's result is that players choose constrained maximization in the PD.

Complementing this work, Brennan and Hamlin (2000) consider the available dispositions. They propose substituting the hypothesis of blind self-interested maximisation with the

[26] Note that in the psychology literature, disposition is usually synonymous with trait. A predisposition to have a given identity is something fixed. For Gauthier, however, dispositions refer to inclinations that may change according to the situation; in other words, they are dynamic.

hypothesis of competing motivations, of which self-interest is one. They argue that: "*the disposition of rational egoism is not the disposition that will make your life go best for you. Your expected lifetime pay-off may be larger if you were to have a different disposition. (The analysis of rational trustworthiness is a relevant example here). If this is true, the disposition of rational egoism (the strict homo economicus disposition) is self-defeating in Parfit's sense; and it would be in your own interest to choose a different disposition if only that is possible*" (Brennan and Hamlin, 2008, p. 80). This is the perspective we adopt in order to give support to Berge equilibrium and to apply Gauthier's assumption that individuals have two dispositions available to them: to adopt Berge or Nash behaviour rules. Below we offer some examples of how we propose to proceed.

First we consider a well known cooperation game situation, the trust game, where Y < 0 < X < Z.

		Player 2	
		Honor	Exploit
Player 1	Trust	X,X	Y,Z
	Distrust	0,0	0,0

Observe that for player 2, Exploit is a weakly dominant strategy. The Nash equilibrium (Distrust, Exploit) is unique as is the Berge equilibrium (Trust, Honor).

Assume that players are paired randomly. They have the choice between two dispositions based on the Nash behaviour rule (NR) or the Berge behaviour rule (BR). We call the NR player the first type and the BR player the second type. Players follow BR when they expect their partner to do the same, and the choice to be of one type rather than the other depends on the relative expected utilities. The probability to play as a type 1 or a type 2 is even. We use α to denote the share of BR players in the population. First, supposing that before the game starts, players know both their own and their partners' types, then the expected utilities of NR and BR players are respectively EU(NR) = 0 and EU(BR) = αX. For any $\alpha > 0$, the expected utility of BR players is strictly higher than the expected utility of NR players; if $\alpha = 0$, the expected utilities of the two types of players are even. To be a BR player improves welfare as soon as there are other BR players in the population with whom trust relations can be established. Otherwise, if the BR player is unique, he/she will play as if a NR player.

If we relax the assumption that individuals can identify the type of their partner, the result remains robust. To see this, assume that both BR and NR players fail to identify those with whom they interact. Let β be the probability that BR players identify each other and θ the probability that they fail to identify NR players. The expected utilities of BR and NR players are respectively:

$$EU(BR) = \alpha\beta X + (1-\alpha)\frac{\theta Y}{2} \text{ ; } EU(NR) = \frac{\alpha\theta Z}{2}.$$

and an individual chooses to be a BR player if : $\dfrac{\beta}{\theta} > \dfrac{\alpha Z - (1-\alpha)Y}{2\alpha X}$. (3)

If condition (3) is fulfilled, players adopt BR even though they may interact unknowingly with NR players. Two remarks follow. First, when the proportion of BR players increases, $\dfrac{\beta}{\theta}$ also increases, lowering the risk of mistaking NR players for BR players. Second, when the relative gain from cooperation increases, condition (3) becomes less constraining, making BR more attractive. We deduce that individuals will be more likely to adopt BR when the magnitude of the social dilemma is important and when their social environment is not too egoistic. To illustrate this, let X = 2, Y = -1, Z = 4 and α = 1/2. Individuals choose to follow BR only if $\dfrac{\beta}{\theta}$ is to be at least equal to 5/4. That is, when the probability of achieving mutual recognition is at least 1.25 times higher than the probability of failing to recognize a NR player.

Considering other game situations could lead to the opposite result, in which case NR is preferred. This applies to zero-sum games in most competitive situations and even in cooperation games where interests are not conflicting. Consider, for example, the following game:

		Player 2	
		C	D
Player 1	C	3,3	4,1
	D	1,4	2,2

There is a unique Nash equilibrium at (C,C) and a unique Berge equilibrium at (D,D). Letting individuals choose their disposition before the game starts, we deduce that the best option for players is to play in a Nash fashion. To see this, first let individuals know the type of their partners. We have: EU(NR) = 3 and EU(BR) = 3 - α and for any $\alpha > 0$, it pays to choose a NR disposition. Now let us assume that individuals do not know the type of their partner. We have U(NR) = $\alpha\theta + 3$ and U(BR) = $\alpha(2\theta - \beta) + 3 - 2\theta$ and we deduce that U(NR) > U(BR) leads to inequality $\frac{\beta}{\theta} > \frac{(\alpha - 2)}{\alpha}$. This is always true and individuals always choose to play in a NR fashion.

This disposition-based approach can be applied to any game situation to indicate when either Berge equilibrium or Nash equilibrium should be applied. The choice in each case will rely on the utility structure of the game and on the players' subjective probabilistic appreciation of the types of partners with whom they are interacting.

4 Conclusion

This paper initiates progress toward the inclusion of moral principles in behaviour rules. Complementarily to the other-regarding preferences approach, which adds moral expressions into the utility function of players, we question the conventional view that the Nash rule may be appropriately applied to every game situation. We depict decision making within a situational perspective and assume that individuals' behaviour rules vary according to the situations faced. We focus on 2×2 game situations and contend that in cooperative situations, social norms, including reciprocity and kindness, suggest that individuals often play in a mutually supportive fashion.

Mutual support does not capture the many idiosyncratic moral principles observed in the experimental literature, and we do not aim to provide here an exhaustive treatment of situational decision-making. Rather, our objective as a first step towards designing a situational decision-making theory is to focus on a simple behaviour rule as it complements Nash. This behaviour rule is mutual support, and to model it, we revive non-cooperative Berge equilibrium. Studying the conditions of its existence, we show that Nash and Berge equilibrium are strongly related and we define a simple method to link the two.

Because playing in a Berge fashion is not immune to deviation, we examine the rationale for playing in this way. Assuming that individuals play according to either behaviour rule, we show, *à la* Gauthier, that a player may be well-off playing a Berge behaviour rule in some game situations even when no repetition or punishment mechanisms exist. The disposition approach is, *per se*, an operational approach that dictates which behaviour rule is played and when.

In terms of further, related research, there are three lines that we see as being particularly appealing. The first would be an experimental paper which complements this conjectural paper by implementing experiments to justify the assumptions made herein. Along the lines of Henrich *et al.* (2004, 2010), we are interested in better understanding when individuals tend towards one behaviour rule or another. In this pursuit, we may follow the situational taxonomy of Reis (2008) in particular. The second enquiry is theoretical and relates to one of our companion papers on the properties of N-player Berge equilibrium. We saw in the examples considered above, that for PD, CG, taxation, and trust games, Berge equilibria are Pareto-optimal. However, this is not always the case**,** and therefore an interesting avenue of future research may be to define the classes of games for which Berge equilibrium is Pareto-optimal and always Pareto-dominated. To conclude, we have attempted to show that the Berge rule may be appropriate to understand human behaviours in some situations, while the Nash rule may be more appropriate in others. This is inevitably a simplification, and we suspect that additional rules may complete these two. Careful scrutiny of other behaviour rules and their axiomatic and theoretical properties present the next step for defining a situational theory of decision making.

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