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A unified approach to comparative statics puzzles in experiments

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ABSTRACT: Many experimental studies implement two versions of one game for which agents' behavior is fundamentally different even though the Nash prediction is the same. This paper provides a novel explanation of such findings. Starting from the observation that many of the games under consideration satisfy the strategic-complementarity property, I obtain predictions for the direction of adjustment in response to parameter changes which do not require calculation of the equilibrium. I show that these predictions are in line with the experimental evidence. Further, I provide a behavioral justification of the approach, and I explore the relation to alternative explanations based on equilibrium selection theories and the quantal response equilibrium.

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1 Introduction

Laboratory experiments have cast doubt on the predictive value of the Nash equilibrium and its refinements. At least the joint hypothesis that monetary payoffs are maximized and the Nash equilibrium is played is often in conflict with the facts.¹ Nevertheless, in some ways the behavior of experimental subjects often “looks right” intuitively. For instance, as pointed out by Samuelson (2005), even when point predictions do not hold, comparative-statics predictions may still be borne out in the lab. However, even the comparative-statics predictions derived from the Nash equilibrium often do not hold.² For instance, in an insightful contribution, Goeree and Holt (2001), henceforth GH, report the results of ten pairs of experiments where the Nash equilibrium is the same in both cases, but nevertheless subjects behave differently. Thus, not only the point predictions are wrong, but even the comparative-statics implication that behavior should not be affected by the parameter change fails to hold.

I shall argue that nevertheless well-known *monotone comparative statics* techniques based on the Nash equilibrium can be used to explain the observed treatment effects. Results of Milgrom and Roberts (1990) and Vives (1990) provide comparative-statics predictions that do not rely on calculation of the Nash equilibrium. The results can explain the treatment effects in the GH experiments and many similar observations very well, without yielding point predictions. The argument relies on basic structural properties such as whether the parameter shift has a monotone effect on the incremental payoffs from increasing actions and, similarly, whether the other players’ actions also have such monotone effects on a player’s incremental payoffs. By focusing on

¹For instance, subjects only rely on increasing difference to a limited extent (Beard and Beil 1994). Deviations from the Nash prediction also occur in games where social preferences matter, including public goods games (Ledyard 1995), ultimatum games (Güth et al. 1982) and trust games (Fehr et al. 1993).

²Samuelson himself points out the limitations of his statement, mentioning bargaining experiments of Ochs and Roth (1989) where the effects of the discount factor and the length of the game are inconsistent with standard predictions.

such general structural properties rather than on the specific payoff functions, one can predict the direction of the treatment effect while allowing for the possibility that there is no change at all. This *structural approach* based on the literature on games with strategic complementarities has so far not been used to explain treatment effects in experiments.³

I shall also compare my approach with well-known alternatives. First, I will show that, in games with multiple parameter-independent Nash equilibria the comparative-statics predictions of equilibrium selection theories such as risk dominance and potential maximization coincide with those obtained by the structural approach. Second, while there are similarities between the structural approach and comparative-statics theories based on the quantal response equilibrium of Mc Kelvey and Palfrey (1995), the former offers a simple unified approach to a wide class of related phenomena, only some of which have been explained by the quantal response equilibrium.

In Section 2, I will sketch three of the GH examples. In Section 3, I will use one of them to illustrate the structural approach for certain games with strategic complementarities, namely supermodular games. In Section 4, I will extend the approach beyond this class. Section 5 will deal with the relations between the structural approach and alternatives based on equilibrium selection theories and on the quantal response equilibrium. Section 6 delves deeper into the behavioral foundations of the approach. Section 7 concludes.

2 Introductory Examples

I shall first sketch three of the ten GH examples.

(i) In the *Kreps game*, players choose actions from $X_1 = \{0, 1\}$ and $X_2 = \{0, 1, 2, 3\}$, respectively. Payoffs are given as in Table 1, where $\theta \in \mathbb{R}^+$.

For all $\theta \in \Theta$, there are two pure Nash equilibria $((0, 0)$ and $(1, 3)$). In

³A vaguely related experimental contribution of Chen and Gazzale (2004) demonstrates that learning in certain games with strategic complementarities, namely supermodular games, works particularly well. However, the authors do not treat comparative statics.

	$x_2 = 0$	$x_2 = 1$	$x_2 = 2$	$x_2 = 3$
$x_1 = 0$	200, 50	0, 45	10, 30	20, -250
$x_1 = 1$	0, -250	10, -100	30, 30	$\theta + 50, \frac{6}{5}\theta + 40$

Table 1: Kreps Game

addition, there is a mixed-strategy equilibrium where player 1 chooses $x_1 = 0$ with probability $30/31$, and player 2 chooses $x_2 = 0$ with probability $1/21$ and $x_2 = 1$ with probability $20/21$. Thus, the following prediction results:

“If θ increases, the equilibrium structure is not affected.”

However, GH report the following results. For $\theta = 0$, 32% of the subjects in the role of player 1 chose the high action 1; whereas 96% did so for $\theta = 300$. For $\theta = 0$, no subject in the role of player 2 chose $x_2 = 3$, but 84% did so for $\theta = 300$. Thus, the experimental evidence suggests the following conclusion, which violates the above prediction:

“As θ increases, more subjects choose high actions”.

I am interested in this particular observation of GH.⁴ One could of course explain it with selection arguments, based for instance on payoff dominance. However, my goal is to find an explanation of treatment effects that also applies to games with unique parameter-independent Nash equilibria such as the following.

(ii) In the *Traveler’s Dilemma*,⁵ two players $i = 1, 2$ simultaneously choose integers x_i between (and including) 180 and 300. Each player is paid the minimum of the chosen numbers; in addition, the player with the lower number receives a transfer $R > 1$ from the player with the higher number.⁶ Defining

⁴GH emphasize that for $\theta = 0$ many subjects (68%) choose $x_2 = 2$, the only action that is neither part of a pure-strategy equilibrium nor of a mixed-strategy equilibrium.

⁵The game goes back to Basu (1994).

⁶The strategies are interpreted as independent claims of two travelers against an airline that has lost the (identical) luggage of both travelers. The payoff structure corresponds to payment schemes devised by the airline to avoid excessive claims by the travelers.

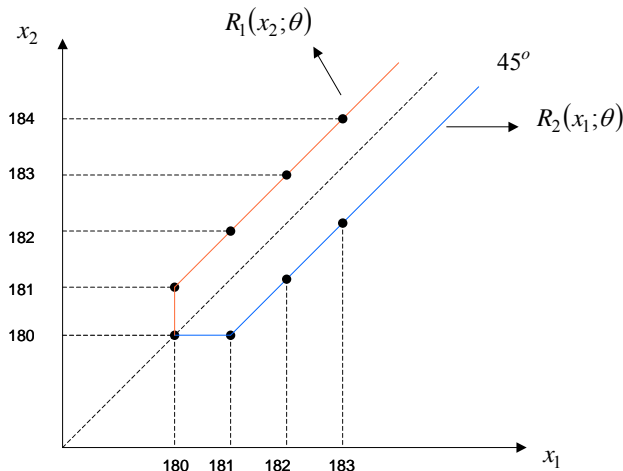


Figure 1: Traveler's Dilemma

$$\theta = -R,$$

$$\pi_i(x_i, x_j; \theta) = \min(x_i, x_j) + \theta \cdot \text{sign}(x_i - x_j). \quad (1)$$

The dots on the lines in Figure 1 give the reaction functions for any $\theta \in \Theta = (-\infty, -1)$. Thus, for all θ the game has a unique Nash equilibrium $x_1 = x_2 = 180$.⁷ GH examined the cases $\theta = -5$ and $\theta = -180$.⁸ For $\theta = -180$, 80% of the subjects chose the lowest possible action, whereas the same fraction chose the highest possible action for $\theta = -5$. Thus, as in the *Kreps Game*, parameter increases induce an increase in players' actions, contrary to what a comparison of Nash equilibria for the specific game would suggest.

(iii) In the *common-interest proposal game* (GH, Figure 3), two players move sequentially, according to the game tree in Figure 2.⁹ Thus, the strategy spaces are $X_1 = X_2 = \{0, 1\}$. The parameter space is $\Theta = (0, 60)$. For

⁷This equilibrium is also the unique rationalizable strategy profile.

⁸Similar results have been obtained by Capra et al. (1999) for other parametrizations.

⁹I use the name "common-interest proposal game", because $(0, 0)$ is the optimal outcome for both players.

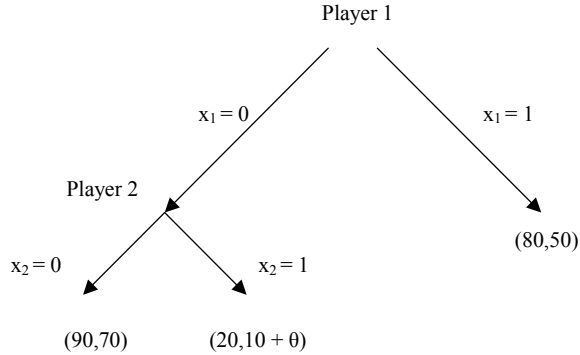


Figure 2: A Common-Interest Proposal Game

all $\theta \in \Theta$, the unique subgame perfect equilibrium is $x_1 = x_2 = 0$. GH considered $\theta = 0$ and $\theta = 58$. For $\theta = 0$, 84% of the subjects in the role of player 1 and all the subjects in the role of player 2 chose equilibrium actions $x_i = 0$. For $\theta = 58$, however, the corresponding figures are only 46% and 75% respectively. Hence, higher parameter values lead to higher actions.

Summing up, the following three cases arise: (i) multiple pure-strategy equilibria, (ii) a unique pure-strategy equilibrium, or (iii) a unique subgame-perfect equilibrium. In all these examples, however, the set of pure-strategy equilibria is parameter-independent, but there are nevertheless clear treatment effects.

3 Introducing the Structural Approach

I will now introduce the *structural approach* to explaining treatment effects like those in the above examples. All these games satisfy certain assumptions that I will maintain throughout the paper. There are players $i = 1, 2$, strategy spaces X_i and payoff functions $\pi_i(x_i, x_j, \theta)$, where θ is from some partially

ordered set Θ , and the following assumptions hold.¹⁰

1. X_i is independent of θ ;
2. X_i is a compact subset of the real numbers;
3. X_i has a partial order \geq that is independent of θ .¹¹

The structural properties I will rely on to reconcile theory and evidence concern the incremental payoff from increasing actions, defined as follows.

Definition 1 For $i = 1, 2$, $j \neq i$, $x_i^H > x_i^L$

$$\Delta_i(x_i^H, x_i^L; x_j; \theta) \equiv \pi_i(x_i^H, x_j; \theta) - \pi_i(x_i^L, x_j; \theta).$$

I will use the Kreps game to illustrate the structural approach. Straightforward derivations show that this game has the following two properties:

$$\Delta_i(x_i^H, x_i^L; x_j; \theta) \text{ is non-decreasing in } \theta \quad (\text{ID})$$

$$\Delta_i(x_i^H, x_i^L; x_j; \theta) \text{ is non-decreasing in } x_j \quad (\text{SUP})$$

The first property states that the objective functions $\pi_i(x_i, x_j; \theta)$ have *increasing differences* in $(x_i; \theta)$: An increase in θ has the direct effect of increasing the incremental payoff for each player, or at least leaving it unaffected.¹² Thus, for fixed behavior of the other player, increasing own actions becomes (weakly) more attractive, so that reaction functions are (weakly) increasing in θ .¹³ The second property, *supermodularity* of $\pi_i(x_i, x_j; \theta)$ in (x_i, x_j) ,

¹⁰These assumptions can be weakened considerably. For the purposes of interpreting the experimental evidence, the set-up is sufficiently general.

¹¹Typically, the required partial order on X_i will be the standard order on the real numbers. In some cases, however, in view of the experimental evidence provided by GH it is more natural to consider coarser partial orders.

¹²For both players, an increase in θ raises the benefit from choosing the highest action ($x_1 = 1$ and $x_2 = 3$) rather than any other one, whereas there is no relation between θ and the benefit for player 2 from increasing x_2 from 0 to 1 or 2, or from 1 to 2.

¹³A formal version of this statement relies on Lemma 1 in the Appendix.

says that the payoff increase from increasing x_i is non-decreasing in x_j for $j \neq i$.¹⁴ Thus, the optimal response of player i is non-decreasing in x_j , that is, actions are *strategic complements*. The positive direct effects of higher θ on x_i and the induced indirect effects on x_j are mutually reinforcing. Together, (ID) and (SUP) therefore suggest that the equilibrium actions should be non-decreasing in θ . This intuition is formalized in the following proposition which is an implication of more general results from the theory of supermodular games (e.g., Milgrom and Roberts 1990).

Proposition 1 *Suppose (ID) and (SUP) hold. Then*

- (i) *A smallest and a largest pure-strategy Nash equilibrium exist.*
- (ii) *For both equilibria, the actions of each player are non-decreasing in θ .*

Statement (i) not only guarantees existence of a Nash equilibrium, but also makes sure that the smallest and largest equilibrium are well-defined objects.¹⁵ Part (ii) provides a comparative-statics prediction on these objects that is fully in line with the empirical evidence for the *Kreps Game*, namely:

“If θ increases, the equilibrium actions increase or remain unaffected.”

The overly strong independence prediction obtained by simple comparison of Nash equilibria for different parameter values is a boundary case of the prediction of Proposition 1 that the equilibrium is non-decreasing in θ . While the independence prediction does not survive empirical scrutiny because a change in θ changes the observed actions, the weaker comparative-statics prediction is consistent with the facts.

This argument illustrates the central message of the paper: By forgetting details of the game and focusing instead on basic structural properties,

¹⁴For instance, for player 1, the incremental payoffs increase from -200 to 10 , 20 and finally $\theta + 30$ as player 2 increases his actions from 0 to 3 .

¹⁵The smallest equilibrium exists if and only if the profile consisting of the minimal equilibrium action for each player is itself an equilibrium; similarly for the largest equilibrium. Of course, the smallest and largest equilibrium may coincide for some or all values of θ .

one obtains a weak comparative-statics prediction that is consistent with the experimental evidence. I shall show that this *structural approach* is a powerful tool for explaining comparative-statics puzzles in laboratory experiments. Most immediately, the same logic can be applied with minor changes to three other examples investigated by GH. The common-interest proposal game as well as the closely related *conflicting-interest proposal game*¹⁶ and the *extended coordination game* also satisfy (SUP) and (ID) with respect to the relevant parameters and suitable partial orders. In all three cases, there are clear treatment effects, even though the equilibrium set is independent of θ . Again, Proposition 1 provides weak comparative-statics predictions that match the facts.¹⁷ Another application concerns *public goods experiments* as surveyed by Ledyard (1995), which display clear behavioral effects of the return on investment which again cannot be captured by comparison of Nash equilibria. The games satisfy (ID), and (SUP) holds trivially because payoffs are additively separable.

The very fact that the predictions of the structural approach are consistent with the experimental evidence is a strong argument in its favor. In addition, the intuition for this observation is straightforward. Even subjects who, for whatever reason, do not display Nash behavior, are very likely to understand the two basic structural properties: They should understand (i) that high incremental payoffs make high actions attractive for given actions of the other player and (ii) that, if incremental payoffs increase with the other player's action, then they should react to higher actions by choosing higher actions themselves. If players understand these two properties, and if they believe that other players apply the same reasoning, then they should choose high actions for high parameter values.

¹⁶This game is described in Figure 4 of GH.

¹⁷Details of the arguments are available upon request.

4 Beyond Supermodular Games

This section shows how the structural approach can be extended to many games satisfying weaker properties than (SUP) and (ID). In this fashion, the evidence from three more GH examples can be explained.

4.1 General Games with Strategic Complementarities

It is straightforward to show that the traveler's dilemma is not supermodular. Nevertheless, the observed changes can be understood by reference to the essential structural properties of the game.¹⁸

First, note that (ID) still holds. Thus, an increase in θ puts outward pressure on the reaction functions by increasing incremental payoffs.¹⁹ To see this, first note that, because of the term $\min(x_i, x_j)$ in the payoff function, there is an incentive to choose high actions. The term $\theta \cdot \text{sign}(x_i - x_j)$ acts as a counterbalance, but less so as θ approaches zero from below. Therefore, the incremental payoff from increasing x_i is non-decreasing in θ , and (ID) is satisfied. Thus, even though θ has no effect on the reaction function in the specific example, it has a structural property which implies that player i 's reaction to x_j is weakly increasing in θ .²⁰ The traveler's dilemma corresponds to the boundary case where the reaction functions are unaffected by the parameter change even though (ID) holds.

Second, the following strategic-complementarity property holds, which is reflected in Figure 2:

Both players have non-decreasing reaction functions $R_i(x_j; \theta)$. (SC)

Ignoring all details of the game structure except (ID) and (SC) suggests that a parameter increase has the direct effect of increasing actions for both players, and that these effects are mutually reinforcing, so that the equilibrium should

¹⁸Similar arguments can be made for the auction game of GH.

¹⁹Lemma 1 in the Appendix provides a formal argument.

²⁰Again, Lemma 1 in the Appendix provides the formal justification of this argument.

increase with θ . This intuition is correct under additional conditions which hold in the Traveler's Dilemma.²¹

Proposition 2 *Suppose (SC) and (ID) hold, for each $\theta \in \Theta$, reaction functions are well-defined, and a symmetric pure-strategy equilibrium $(x_1(\theta), x_2(\theta))$ exists. Finally, suppose the following stability condition (STAB) holds:*

*If $x_1 < x_1(\theta)$ and $x_2 < x_2(\theta)$, then $x_2 < R_2(x_1; \theta)$ or $x_1 < R_1(x_2; \theta)$;
if $x_1 > x_1(\theta)$ and $x_2 > x_2(\theta)$, then $x_2 > R_2(x_1; \theta)$ or $x_1 > R_1(x_2; \theta)$.*

Then $x_i(\theta)$ is non-decreasing in θ for $i = 1, 2$.

Proof. See Appendix ■

(STAB) is the discrete analogue of the property that the reaction function for player 1 is steeper than the reaction function for player 2 in (x_1, x_2) -space at the equilibrium. Clearly, (STAB) implies uniqueness of the equilibrium.

The intuition for Proposition 2 becomes clearest in a game with continuous action spaces, as in Figure 3. For this game all the assumptions of Proposition 2 hold. (ID) guarantees that, if an increase in θ affects the reaction curves, it shifts them out. By (SC) these positive effects on players' actions are mutually reinforcing. Thus, as the parameter increases from θ^L to θ^H , both reaction curves shift outwards, resulting in a higher equilibrium.

4.2 Symmetric Games with Increasing Differences

Intuitively, general comparative-statics results require (SUP) or (SC) in addition to (ID) to make sure that indirect effects do not dominate over direct effects: It is, for instance, simple to construct games with strategic substitutes satisfying (ID), such that (say) player 1's actions decrease as θ increases. This can happen if reaction functions shift out strongly for player 2, but less so for player 1. Then the direct effect that player 1's reaction function shifts

²¹I am not aware of any formal statement of this result elsewhere, but Vives (2005) hints at the possibility of such generalizations.

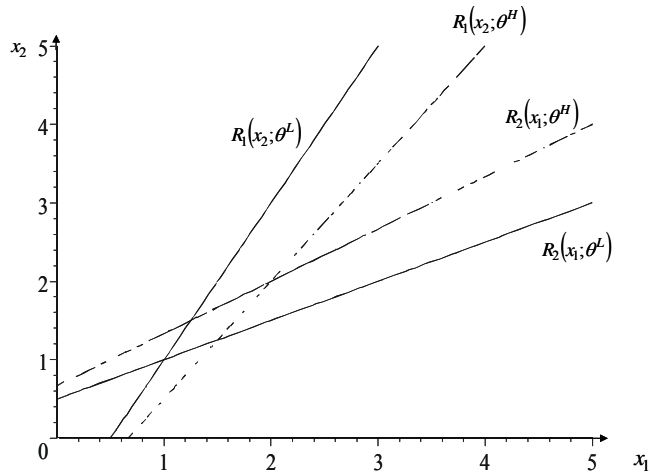


Figure 3: Comparative Statics with Continuous Action Spaces

out, inducing him to choose higher actions, will be overwhelmed by the indirect effect that player 1 reacts to the higher action of player 2 implied by the strong outward shift of player 2's reaction function with a substantial reduction in his own action. In symmetric settings, however, strategic complementarity is no longer required. Though I shall not state the result formally, it is simple to show that condition (SC) in Proposition 2 is unnecessary as long as one considers only symmetric equilibria in symmetric games.

4.3 Parameters Affecting only one Payoff Function

Even for asymmetric games that do not satisfy (SC), the structural approach is sometimes useful. A case in point is *generalized matching pennies*, with $X_i = \{0, 1\}$ and $\Theta = (40, \infty)$.

The payoffs are given in Table 2. Identify a mixed strategy of player i , σ_i , with the probability of choosing action 1. Figure 4 plots the reaction correspondences for $\theta \in \{44, 80, 320\}$. For all $\theta \in \Theta$, the reaction correspondence for player 2 is given by the same dashed line $R_2(\sigma_1; \theta)$, while it

	$x_2 = 0$	$x_2 = 1$
$x_1 = 0$	$\theta, 40$	$40, 80$
$x_1 = 1$	$40, 80$	$80, 40$

Table 2: Payoffs in the Generalized Matching Pennies Game

depends explicitly on θ for player 1. The unique mixed-strategy equilibrium is $\sigma_1^* = \frac{1}{2}$, $\sigma_2^* = 1 - \frac{40}{\theta}$. Thus, unlike in the earlier examples, only player

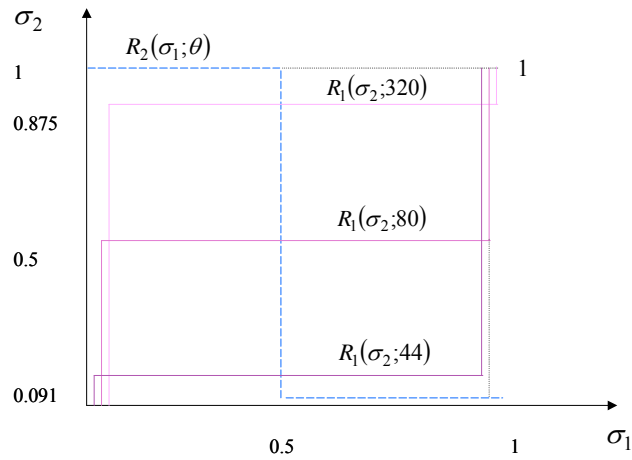


Figure 4: Generalized Matching Pennies

1's equilibrium action is independent of θ : Player 2's choice x_2 is increasing in θ , as the probability with which $x_2 = 1$ is played increases in θ . As θ increases from 44 to 80 and 320, the percentage of subjects in the role of player 1 choosing the high action decreases from 92% to 52% and then to 4%, whereas the corresponding values for player 2 increase from 20% to 52% and then to 84%. Thus, contrary to the prediction of the mixed-strategy equilibrium *both* players' actions change as θ does. Intuitively, as player 1's payoff function satisfies (ID) with respect to $(-x_1, \theta)$,²² an increase in θ di-

²²This means that $\Delta_1(x_1^H, x_1^L; x_2; \theta)$ is non-increasing in θ .

rectly reduces his incremental benefits from higher actions.²³ Next, because $\pi_2(x_2, x_1; \theta)$ is supermodular in $(x_1, -x_2)$,²⁴ a reduction in x_1 from 1 to 0 has the indirect effect of increasing the incremental benefit for player 2 from increasing x_2 from 0 to 1.²⁵ These properties suggest that, when θ increases, player 1's action should decrease, whereas player 2's action should increase.

I first prove such a comparative-statics result for games with four structural properties that hold for generalized matching pennies, but one additional requirement that obviously does *not* hold, namely existence of a unique pure-strategy Nash equilibrium.

Proposition 3 *Suppose both players have well-defined reaction functions; and there is a unique pure-strategy Nash equilibrium $\mathbf{x}(\theta)$ for each θ . Suppose further that the following properties hold:*

(SUP₁) $\pi_1(x_1, x_2; \theta)$ is supermodular in (x_1, x_2) .

(SUP₂⁻) $\pi_2(x_2, x_1; \theta)$ is supermodular in $(x_1, -x_2)$.

(ID₁⁻) $\pi_1(x_1, x_2; \theta)$ satisfies increasing differences in $(-x_1, \theta)$.

(IND₂) $\pi_2(x_2, x_1; \theta)$ is independent of θ .

Then $x_1(\theta)$ is non-increasing in θ , and $x_2(\theta)$ is non-decreasing in θ .

Proof. See Appendix ■

By (SUP₁) and (SUP₂⁻), actions are strategic complements for player 1 and strategic substitutes for player 2. Figure 5 suggests why a clear comparative-statics result can be obtained even so. For simplicity, the figure assumes continuous action spaces and presupposes that $R_1(\sigma_2; \theta)$ is *strictly* increasing, whereas $R_2(\sigma_1; \theta)$ is *strictly* decreasing; the proof of Proposition 3 extends the argument to reaction functions that are merely non-decreasing and non-increasing, respectively. Crucially, an increase in the parameter affects only the payoffs of one player, shifting his (increasing) reaction function inwards while leaving the other player's (decreasing) reaction function constant. Hence, the equilibrium must move to the left and upwards.

²³When $x_2 = 0$, this benefit is $40 - \theta$; when $x_2 = 1$, this benefit is independent of θ .

²⁴This means that $\Delta_2(x_2^H, x_2^L; x_1; \theta)$ is non-increasing in x_1 .

²⁵For $x_1 = 1$, this incremental benefit is -40 , for $x_1 = 0$, it is 40 .

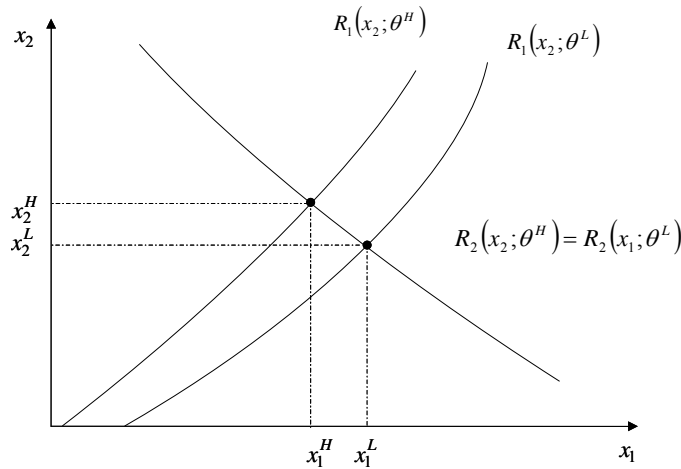


Figure 5: Understanding Generalized Matching Pennies

Even though generalized matching pennies only has a mixed-strategy equilibrium, the result applies. The mixed-strategy equilibrium can be shown to be the pure-strategy equilibrium of a game satisfying the assumptions of Proposition 3. This game has strategy space $\sum_i = [0, 1]$, corresponding to the set of probability distributions on X_i ; payoffs correspond to the expected payoffs of the original game. Hence, again, comparative-statics follow from basic structural properties.

Summing up, the structural approach underlying Propositions 1-3 relies on the following ingredients: First, players are able to abstract. Second, they use this ability to identify basic structural properties of the game. Third, they behave as theory suggests for games with certain basic properties rather than for the particular specification.

Table 3 summarizes the examples discussed so far and provides some additional results that will be introduced below. As reflected in the table, the structural approach can explain the evidence in seven of the ten examples provided by GH. In the remaining three cases, the structural approach does not provide a false prediction. It is simply not applicable because the games do not have suitable structural properties. Loosely speaking, the direct and

Nash Prediction	Game	Observed Actions	Reason
Unique pure Nash equilibrium independent of θ	Traveler's dilemma (Capra et al. 1999, GH) Public goods games (Ledyard 1995)	Increasing in θ	Prop. 2 Prop. 1
Unique SPE independent of θ	Proposal games (GH Fig. 3 and 4)	Increasing in θ	Prop. 1
Unique mixed equilibrium: increasing in θ for player 2, constant for player 1	Matching pennies (Ochs 1995, GH)	Player 2: increasing Player 1: decreasing	Prop. 3
Unique Bayesian Equilibrium independent of θ	Auction game (GH)	Increasing in θ	Prop. 2
Multiple pure equilibria; mixed equilibrium is independent of θ	Kreps game (GH) Extended coordination game (GH)	Increasing in θ	Prop. 1
Multiple pure Nash equilibria where mixed equilibrium is decreasing in θ	Effort coordination (Van Huyck et al. 1990, Goeree and Holt 2005) Wolf's dilemma (Huettel-Lockhead 2000)	Increasing in θ	Prop. 1
Period-2 equilibrium independent of first-period play	Capacity game (Brandts et al. 2003)	Period-2 actions increasing in own period-1 action, decreasing in opponent's.	Prop. 1

Table 3: Summary of Results

indirect effects of parameter changes are not mutually reinforcing, so that general comparative-statics results cannot be derived.

5 Comparison with Alternative Approaches

Clearly, there are alternative approaches to the issues just raised. First, in situations with multiple equilibria, selection theories provide similar answers. Second, for some of the above examples, the quantal response equilibrium (McKelvey and Palfrey (1995)) can be used to explain the comparative statics. I shall explore the relation of the structural approach to both alternatives.

5.1 Equilibrium Selection

The predictions generated by the structural approach coincide with those obtained by familiar equilibrium selection theories based on risk-dominance and potential maximization.

5.1.1 Effort Coordination Games

To show this, I will start with *effort coordination games*.²⁶ Payoff functions are

$$\pi_i(x_i, x_j; \theta) = \min(x_i, x_j) + \theta \cdot x_i,$$

with $x_i \in \{0, 1, \dots, M\}$ and $\theta = -c$ for some effort cost parameter $c \in (0, 1)$. For $c < 1$, the set of pure-strategy equilibria is the diagonal (given by $x_1 = x_2$). Thus, if one uses the set of pure-strategy equilibria to predict responses to parameter changes, increases in costs should have no effect on

²⁶Several authors have analyzed the effects of changing various parameters in other 2×2 -coordination games satisfying (SUP) and (ID). For instance, in the experiments of Huettel and Lockhead (2000), Schmidt et al. (2003), and most of the experiments of Guyer and Rapoport (1972), the comparative-statics predictions correspond exactly to those obtained from the *Embedding Method*, and the arguments are similar as in the following discussion of effort coordination games. The propositions of this paper are not applicable for the “Benefit-to-other”-treatment of Guyer and Rapoport, because (ID) does not hold.

equilibrium effort. The comparative statics become more counter-intuitive if one allows for mixed-strategy equilibria. For instance, for $X_i = \{0, 1\}$, there is an equilibrium such that each player chooses $x_i = 1$ with probability c . Thus, as costs increase, agents put more weight on the high effort level, so that, paradoxically, effort *increases* with costs. Unsurprisingly, experimental results (van Huyck et al. 1990; Goeree and Holt 2005) show that for lower c more subjects choose higher effort.

The structural approach resolves the tension between theoretical predictions and empirical observations. Effort coordination games are supermodular, because the net benefit from increasing effort is $1 - c > 0$ if the original effort level is smaller than the effort of the other player, and $-c < 0$ otherwise. Thus, the net benefit from increasing effort is non-decreasing in the effort of the competitor. Also, $\pi_i(x_i, x_j; \theta)$ satisfies (ID). Therefore, Proposition 1 predicts that both the smallest and the largest pure-strategy equilibrium are non-decreasing in θ . This result is compatible with the standard prediction that the set of pure-strategy equilibria is independent of θ , but also with the empirical evidence that agents choose higher actions as θ increases.

5.1.2 Risk Dominance and Potential Maximization

The approach just outlined fits nicely with selection criteria such as risk-dominance (Harsanyi and Selten 1988). In a symmetric 2×2 – game with two pure-strategy equilibria (a, a) and (b, b) , (a, a) is *risk-dominant* if both players prefer a if they expect the other player to choose a and b with probability $1/2$ each. Risk dominance predicts that equilibria with higher effort levels are chosen as costs decrease (Goeree and Holt 2005). More generally, the comparative statics implied by Proposition 1 and by risk dominance coincide, as the following result shows.

Proposition 4 *Suppose $X_i = \{0, 1\}$, and (ID) holds for the standard order on $\{0, 1\}$. Suppose that the set of Nash equilibria is $\{(0, 0), (1, 1)\}$ for all $\theta \in \Theta$. Then, if $(1, 1)$ is selected by risk-dominance for θ^L ; it is also selected for $\theta^H \geq \theta^L$.*

Proof. See Appendix. ■

The generalization of risk-dominance to games with more than two players or continuous actions is not obvious. An alternative approach to equilibrium selection is available for potential games (Monderer and Shapley 1996, Goeree and Holt 2005). Such games are characterized by the existence of a potential $V(x_1, x_2; \theta)$ with the defining property that $\pi_1(x''_1, x_2; \theta) - \pi_1(x'_1, x_2; \theta) = V(x''_1, x_2; \theta) - V(x'_1, x_2; \theta)$ for all $x'_1, x''_1 \in X_1$, $x_2 \in X_2$, $\theta \in \Theta$, and analogously for π_2 .²⁷ Potential-maximizing strategy profiles are pure-strategy equilibria, but the converse is not necessarily true (Monderer and Shapley 1996): In games with multiple equilibria such as effort coordination games, there is a unique potential-maximizing profile which can be used for equilibrium selection. Monderer and Shapley (1996) have already argued that the observed effects of increasing effort costs can be explained using potential maximization, showing that, in the experiments of van Huyck et al. (1990), potential maximization selects the lowest equilibrium for high effort costs and the highest equilibrium for low effort costs. More generally, potential maximization and the structural approach have the same comparative-statics implications.

Proposition 5 *In a symmetric game with differentiable objective functions satisfying (ID), suppose (x^H, x^H) and (x^L, x^L) are unique potential maximizers for θ^H and θ^L ($\theta^H \geq \theta^L$), respectively. Then $x^L \leq x^H$.*

Proof. See Appendix. ■

Summing up, the *structural approach* yields comparative-statics predictions that are compatible with standard selection methods where they apply. However, this statement does not extend to payoff dominance. For $\theta \in [-1, 1]$, the game in Table 4 satisfies (ID) and (SUP), but the payoff-dominant equilibrium is $(1, 1)$ for $\theta < 0$, $(0, 0)$ for $\theta > 0$, and thus decreasing in θ .

²⁷With continuously differentiable games, this boils down to the requirement that the partial derivatives of V with respect to each x_i coincide with those of $\pi_i(x_i, x_j; \theta)$.

	$x_2 = 0$	$x_2 = 1$
$x_1 = 0$	$0, 0$	$-2 - 2\theta, -2 + \theta$
$x_1 = 1$	$-2 + \theta, -2 - 2\theta$	$-\theta, -\theta$

Table 4: Payoff Dominance versus Structural Approach Game

5.2 Quantal Response Equilibria

The most popular approach to the kind of puzzles described in this paper is based on the *quantal response equilibrium* (QRE) introduced by Mc Kelvey and Palfrey (1995). This equilibrium concept does not presuppose that players choose best responses to the expected behavior of others. Instead, they make errors. A QRE requires that each player's error distribution matches the assumed distribution determining expected payoff for each choice. The QRE shares an important property with the structural approach: Unlike the Nash equilibrium, both theories imply that changes in the magnitude of incremental payoffs can have behavioral effects even when they do not change the signs of the incremental payoffs. Contrary to the structural approach, however, the QRE specifies a particular story about how and why agents deviate from equilibrium, which is quite appealing. However, the fact that the structural approach does not require such a specific story to predict comparative statics may also be regarded as an advantage. Several stories concerning the deviations of agents for any given parameter value can be told; one example will be provided in Section 6, but it is unnecessary to do so as long as one is concerned with comparative statics.

An example of the QRE is the *logit equilibrium* which specifies the choice probabilities as being proportional to an exponential function of expected payoffs. The logit equilibrium has been used to explain the treatment effects in the traveler's dilemma (Anderson et al. 2002, Capra et al. 1999), effort coordination games (Anderson et al. 2001, 2002) and generalized matching pennies (Goeree et al. 2003, Mc Kelvey and Palfrey 1995). In some cases, the

authors provide comparative-statics results for the specific game.²⁸ Anderson et al. (2002) pursue a more general line of reasoning. Like the structural approach, their Proposition 3 exploits general properties of the game to derive comparative-statics results. First, the *local payoff property* requires that the expected payoff derivative with respect to own actions depends only on one's own action, exogenous parameters and the distribution and density of the other player's actions. The second property is that, given a distribution of expected play by the opponent, the marginal expected payoff associated with an increase in a player's action is increasing in the parameter. Finally, the proposition requires symmetry. Thus, there is some similarity between the result of Anderson et al. and the one mentioned (but not proved) in Section 4.2 that also relies on symmetry and increasing differences to explain the observed comparative statics.

Nevertheless, the structural approach offers some additional insights. First, Propositions 1-3 do not rely on symmetry. This is important because several of the GH experiments are not symmetric. Second, the local payoff property is not needed to derive the results. Third, properties such as (SUP), (ID) and (SC) are expressed directly in terms of the (deterministic) payoffs, without reference to assumptions on the distribution of the other player's actions. Finally, and related to these points, the quantal response equilibrium seems less generally applicable. Instead of using the quantal response equilibrium, for instance, GH appeal to equity aversion to interpret the proposal games, and they only offer a heuristic explanation for the Kreps Game.

Summing up, the QRE and the structural approach often lead to the same comparative-statics predictions because they are based on the same intuition that effects of parameters on payoff differentials should matter even when they leave the Nash equilibrium unaffected. The theories are complementary in that the QRE offers a fairly rich but specific interpretation of the observations whereas the structural approach is agnostic about the particular sources of deviation from the Nash equilibrium, thus providing a simpler way

²⁸See, for instance, Anderson et al. (2001) for effort coordination games

of predicting treatment effects. Because of the similarities between the approaches, it would be interesting to investigate the relation in more formally. For instance, one might conjecture that a variant of Proposition 1 holds for the QRE rather than the Nash equilibrium, but this is beyond the scope of the present paper.

6 Towards a Behavioral Foundation

In the weak sense of “greater-or-equal”-statements, the aggregate behavior predicted by the structural approach is typically correct. *Why* agents behave in this fashion rather than displaying identical Nash behavior in both cases has only been discussed intuitively so far. I will suggest two alternative, but compatible ways to provide a more thorough behavioral foundation of the observed treatment effects. The first suggestion is to assume that players’ choices correspond to the Nash equilibrium in a game with perturbed payoff functions. The perturbation could come from different sources, including, for instance, social preferences. This approach not only provides weak comparative statics, but also allows for point predictions in principle. The second suggestion is more radical: For an explanation of treatment effects, it is not necessary to have a solution concept for any single game at all. Rather, it suffices to start from a simple set of assumptions about how agents react to a parameter change.

6.1 Nash Equilibria of Perturbed Games

Suppose that, instead of the monetary payoff functions $\pi_i(x_i, x_j; \theta)$, players have perturbed objective functions

$$\widehat{\pi}_i(x_i, x_j; \theta) = \pi_i(x_i, x_j; \theta) + g_i(x_i, x_j; \theta). \quad (2)$$

Suppose that $g_i(x_i, x_j; \theta)$ satisfies (ID) and (SUP) in (x_i, θ) . Then if π_i satisfies (SUP) and (ID), so does $\widehat{\pi}_i$. Thus, even though the Nash equilibrium may differ from the equilibrium in the game with payoff functions π_i ,

Proposition 1 can still be applied to this game. Thus, the equilibrium is still non-decreasing in θ .

Importantly, even if g_i violates (ID) and (SUP), the comparative statics are robust unless the violation is so strong that $\hat{\pi}_i$ does not satisfy (ID) and (SUP) anymore. Perturbations can be arbitrary, as long as the basic structural properties of the game remain unaffected. In fact, the perturbation term need not even be additive.

To illustrate the idea, consider the effort coordination game with $X_i = \{0, 1\}$. For suitable perturbations, (ID) and (SUP) still hold, but the equilibrium set is $(0, 0)$ for low θ and $\{(0, 0), (1, 1)\}$ for high θ . Such perturbations must destroy the symmetric equilibrium $(1, 1)$ for some parameters. Thus, pro-social preferences, which introduce a bias towards symmetric equilibria cannot do the job. Rather, suppose agents display “anti-social preferences”, meaning that they gain utility if the other player has exercised useless effort. Thus, let $k > 0$ and consider the effort coordination game with two effort levels and perturbation term $g_i(x_i, x_j; \theta) = k \max(x_j - x_i, 0)$. The payoff matrix of the perturbed game is given in Table 5.

	$x_2 = 0$	$x_2 = 1$
$x_1 = 0$	$0, 0$	k, θ
$x_1 = 1$	θ, k	$1 + \theta, 1 + \theta$

Table 5: Payoffs in the Perturbed Effort Coordination Game

Suppose $k < 1$. Then the perturbed game still satisfies (ID) and (SUP), and Proposition 1 predicts that the equilibrium set is non-decreasing in θ . Closer inspection reveals that the equilibrium set depends on θ : For high costs ($\theta < -(1 - k)$), the only equilibrium is $(0, 0)$. For low costs ($\theta > -(1 - k)$), there are multiple equilibria, including $(1, 1)$ as well.

Importantly, however, there are many alternative specifications of the perturbation that imply the same comparative-statics. Relying exclusively on the structural approach has the great advantage that it does not presuppose any particular specification of the perturbation terms.

6.2 Adjustment to Change

The structural approach can also be justified by showing that the same comparative statics follow from a set of plausible behavioral rules guiding agents' adjustments to parameter changes. To this end, I postulate the existence of a dynamic adjustment process that reflects the mental reaction to change. This adjustment process does not correspond to actual choices made by subjects in a dynamic game, but rather to hypothetic reasoning about one's own incentives and those of the competitor. Period 1 of this process captures the direct effect of the parameter change on both players, abstracting from the strategic interaction between players. In the remaining periods, I let the players take these interactions into account. Importantly, to arrive at comparative-statics conclusions, it is not necessary to refer to any equilibrium concept for a specific game.

Consider shifts of θ from θ^L to θ^H , with $\theta^H \geq \theta^L$. Further denote the resulting adjustment in behavior, that is, the difference in observed actions before and after a parameter increase, as $\mathbf{a}(\theta^L) = (a_1(\theta^L), a_2(\theta^L))$. Suppose that $a_i = \lim_{t \rightarrow \infty} a_i^t$, where the "adjustment actions" a_i^t obey the following rules:

- (ADJ1) Suppose for all $x_i^H, x_i^L \in X_i, x_j \in X_j, \theta^L, \theta^H \in \Theta$ such that $x_i^H \geq x_i^L$ and $\theta^H \geq \theta^L$ the following condition holds:

$$\Delta_i(x_i^H, x_i^L; x_j; \theta^H) \geq (\leq) \Delta_i(x_i^H, x_i^L; x_j; \theta^L). \quad (3)$$

Then $a_i^1 \geq (\leq) 0$.

- (ADJ2) If $\pi_i(x_i, x_j; \theta)$ is supermodular in (x_i, x_j) and $a_j^t \geq 0$ for $t \geq 1$, then $a_i^{t+1} \geq 0$. Conversely, if $a_j^t \leq 0$ for $t \geq 1$, then $a_i^{t+1} \leq 0$.

The two behavioral rules are motivated by intuitive arguments used earlier. (ADJ1) captures the immediate response to change. If (3) holds, for instance, because (ID) is satisfied, then the incremental value of increasing the action increases for fixed behavior of the other players. Thus, each

player's immediate response to a parameter increase is to increase the own action weakly. (ADJ2) reflects indirect effects: Supermodularity guarantees that a player i who thinks that the other player has the immediate impulse to increase his actions following a parameter increase ($a_j^1 \geq 0$) should realize that the marginal value of increasing an action increases even further, which is reflected by (ADJ2) for $t = 1$. Also, (ADJ2) for $t > 1$ guarantees that the entire dynamic adjustment process is monotone increasing when (SUP) and (ID) hold. The following result is immediate.

Proposition 6 *Suppose (SUP) and (ID) hold. Then $(a_1, a_2) \geq 0$ for any adjustment process satisfying (ADJ1) and (ADJ2).*

Similar results hold under the conditions of Propositions 2 and 3.

7 Conclusions

I have introduced the structural approach to derive weak comparative-statics results for games where the Nash equilibria are independent of parameters, but experimental evidence shows clear treatment effects. The resulting comparative-statics predictions are supported by the experimental observations in all cases that I am aware of, in particular, in those analyzed by GH.

Variations of the approach can be applied to problems that do not concern comparative-statics directly. For instance, Brandts et al. (2006) consider a two-stage game of capacity choice. Two players can make costly, but not fully binding capacity commitments C_i before they decide on investments I_i . Payoff functions $\pi_i(I_i, I_j; C_i, C_j)$ are supermodular in $(I_i, -I_j)$ and have increasing differences in $(I_i, I_j; C_i, -C_j)$. The subgame equilibria of the second stage are independent of the first-period choices. Interpreting C_i and C_j as exogenous parameters of the ensuing subgame, however, I_i should be non-decreasing in C_i and non-increasing in C_j for $j \neq i$ according to Proposition 1. This prediction turns out to be correct. Thus, the structural approach not

only yields useful comparative-statics predictions, but it can also be used to predict the relation between players' behavior in earlier and later periods.

In spite of the large number of conceivable applications, it is important to recognize the limitations of the structural approach. First, obviously, the method does not provide point predictions. Second, even though the approach applies to a large class of games, there are examples where the direct and indirect effects of parameter changes are not mutually reinforcing, so that no comparative-statics predictions are possible without relying on the concrete specification.²⁹ Third, I do not claim that the predictions of the structural approach are likely to be immune against falsification by laboratory experiments. To the contrary, I am convinced that cleverly designed experiments can show that there are some games satisfying (SUP) and (ID) for which the observed comparative statics violate Proposition 1. The challenge for future experimental work is to discover under which circumstances such violations of standard comparative-statics results occur.

8 Appendix: Proofs

The following well-known monotone comparative-statics result will be helpful. It is a special case of Topkis (1978).

Lemma 1 *Let $f((x, \tau))$ be a real-valued function defined on $X \times T$, where X is a compact subset of the real numbers and T is a partially ordered set. Suppose f satisfies increasing differences with respect to (x, τ) . Then $g(\tau) \equiv \arg \max_{x \in X} f((x, \tau))$ is a non-decreasing correspondence.³⁰*

In the following applications, X will correspond to the strategy set of one player; τ will be the strategy set of the other player or the parameter θ .

²⁹For instance, three of the ten little treasures of GH belong to this category.

³⁰ $g(\tau)$ is non-decreasing if $\tau^L < \tau^H$ implies $\min g(\tau^L) \leq \min g(\tau^H)$ and $\max g(\tau^L) \leq \max g(\tau^H)$, where the inequalities on X refer to some arbitrary partial order.

8.1 Proof of Proposition 2

Suppose $\theta^H > \theta^L$. Note first that $x_1(\theta^H) > x_1(\theta^L)$ and $x_2(\theta^H) < x_2(\theta^L)$ cannot hold simultaneously because reaction functions are non-decreasing and, by (ID), $R_2(x_1; \theta^H) \geq R_2(x_1; \theta^L)$. Similarly, $x_1(\theta^H) < x_1(\theta^L)$ and $x_2(\theta^H) > x_2(\theta^L)$ cannot hold simultaneously.

Next note that $x_i(\theta^H) < x_i(\theta^L)$ for $i = 1, 2$ is impossible to satisfy. To see this, note that by (STAB), $x_1 < x_1(\theta^L)$ and $x_2 < x_2(\theta^L)$ together imply that $x_2 < R_2(x_1; \theta^L)$ or $x_1 < R_1(x_2; \theta^L)$. By definition, $x_2(\theta^H) = R_2(x_1(\theta^H); \theta^H)$ and $x_1(\theta^H) = R_1(x_2(\theta^H); \theta^H)$. However, by (ID) and Lemma 1 $R_2(x_1(\theta^H); \theta^H) \geq R_2(x_1(\theta^H); \theta^L)$ and $R_1(x_2(\theta^H); \theta^H) \geq R_1(x_2(\theta^H); \theta^L)$, a contradiction.

Further, suppose that $x_1(\theta^H) < x_1(\theta^L)$, $x_2(\theta^H) = x_2(\theta^L)$. This would require $R_1(x_2; \theta^H)$ and $R_2(x_1; \theta^H)$ to intersect to the left of $(x_1(\theta^L), x_2(\theta^L))$, that is for some (x_1, x_2) such that $x_1 < x_1(\theta^L)$ and $x_2 < x_2(\theta^L)$. Therefore, $R_1(x_2; \theta^L)$ would not be single-valued. Similarly, $x_1(\theta^H) = x_1(\theta^L)$, $x_2(\theta^H) < x_2(\theta^L)$ is impossible. Therefore $x_i(\theta^H) \geq x_i(\theta^L)$ for $i = 1, 2$.

8.2 Proof of Proposition 3

Let (x_1^L, x_2^L) be the equilibrium for θ^L . By (SUP₂⁻) and Lemma 1 the reaction function of player 2 is non-increasing in x_1 , and by (IND₂), $R_2(x_1; \theta^L) = R_2(x_1; \theta^H)$. Thus, the equilibrium (x_1^H, x_2^H) for θ^H lies on $R_2(x_1; \theta^L)$, implying

$$x_1^H \leq x_1^L \text{ and } x_2^H \geq x_2^L \text{ or } x_1^H \geq x_1^L \text{ and } x_2^H \leq x_2^L. \quad (4)$$

It therefore suffices to show that $x_1^H \geq x_1^L$ and $x_2^H \leq x_2^L$ cannot hold simultaneously except if both hold with equality. First, I show that $x_1^H > x_1^L$ and $x_2^H < x_2^L$ cannot hold simultaneously. Because $R_2(x_1^H; \theta^H) = R_2(x_1^H; \theta^L)$ is non-increasing by (SUP₂⁻), clearly $x_1^H > x_1^L$ implies $x_2^H = R_2(x_1^H; \theta^H) \geq R_2(x_1^L; \theta^H) = R_2(x_1^L; \theta^L) = x_2^L$. Next, I exclude the possibility that $x_1^H > x_1^L$ and $x_2^H = x_2^L$. This would require that $R_2(x_1; \theta^H) = R_2(x_1^L; \theta^H)$ is horizontal to the right of (x_1^L, x_2^L) ; the analogous statement would have to hold for

$R_1(x_2; \theta^H)$. This would contradict uniqueness of the equilibrium. By similar reasoning I exclude the possibility that $x_2^H < x_2^L$ and $x_1^H = x_1^L$. Therefore (4) requires $x_1^H \leq x_1^L$ and $x_2^H \geq x_2^L$.

8.3 Proof of Proposition 4

(1, 1) is selected by risk-dominance for θ^L if and only if

$$\pi_i(1, 1; \theta^L) - \pi_i(0, 1; \theta^L) \geq \pi_i(0, 0; \theta^L) - \pi_i(1, 0; \theta^L). \quad (5)$$

Applying (ID) to both sides of (5) shows that analogous inequalities hold with θ^L replaced with θ^H , so that (1, 1) is selected by risk-dominance for θ^H .

8.4 Proof of Proposition 5

For $x^L, x^H \in X_1 = X_2$, $\theta \in \{\theta^L, \theta^H\}$, $V(x^L, x^L; \theta) - V(x^H, x^H; \theta) = V(x^L, x^L; \theta) - V(x^H, x^L; \theta) + V(x^H, x^L; \theta) - V(x^H, x^H; \theta)$.

Thus, if $x^L > x^H$, the definition of the potential function thus implies

$$\begin{aligned} V(x^L, x^L; \theta) - V(x^H, x^H; \theta) = \\ \pi_1(x^L, x^L; \theta) - \pi_1(x^H, x^L; \theta) + \pi_2(x^L, x^H; \theta) - \pi_2(x^H, x^H; \theta). \end{aligned}$$

Using (ID), therefore, for $\theta^H > \theta^L$

$$V(x^L, x^L; \theta^H) - V(x^H, x^H; \theta^H) \geq V(x^L, x^L; \theta^L) - V(x^H, x^H; \theta^L).$$

Further, because x^L is the unique maximizer of the potential function for θ^L ,

$$V(x^L, x^L; \theta^L) - V(x^H, x^H; \theta^L) > 0.$$

Taking the last two inequalities together, x^H cannot maximize the potential for θ^H , which contradicts its definition.

9 References

- Amir, R. (2005): Supermodularity and Complementarity in Economics: An Elementary Survey, *Southern Economic Journal* 71, 636 – 660.
- Anderson, S., Goeree, J. K., and Holt, Charles A. (2001): Minimum-Effort Coordination Games: Stochastic Potential and Logit Equilibrium, *Games and Economic Behavior* 34, 177 – 199.
- Anderson, S., Goeree, J. K., and Holt, Charles A. (2002): The Logit Equilibrium: A Perspective on Intuitive Behavioral Anomalies, *Southern Economic Journal* 92, 21 – 47.
- Basu, K. (1994): The Traveler’s Dilemma: Paradoxes of Rationality in Game Theory, *American Economic Review* 84, 391 – 395.
- Beard, T.R., and Beil, R. (1994): Do People Rely on the Self-interested Maximization of others? An Experimental Test, *Management Science* 40, 252 – 262.
- Brandts, J., Cabrales, A., and Charness, G. (2006): Entry deterrence and forward induction: An experiment, *Economic Theory*, forthcoming.
- Capra, M., Goeree, J. K., Gomez, R., and Holt, Charles A. (1999): Anomalous Behavior in a Traveler’s Dilemma, *American Economic Review* 89, 678 – 690.
- Chen, Y. and Gazzale, R. (2004): When Does Learning in Games Generate Convergence to Nash Equilibria? The Role of Supermodularity in an Experimental Setting, *American Economic Review* 94, 1505 – 1535.
- Fehr, E., Kirchsteiger, G., and Riedl, A. (1993): Does Fairness Prevent Market Clearing? An Experimental Investigation, *Quarterly Journal of Economics* 108, 437 – 460.
- Goeree, J. K., and Holt, Charles A. (2001): Ten little Treasures of Game Theory and Ten Intuitive Contradictions, *The American Economic Review* 91, 1402 – 1422.
- Goeree, J. K., and Holt, Charles A. (2005): An Experimental Study of Costly Coordination, *Games and Economic Behavior* 51, 349 – 364.

- Goeree, J. K., Holt, Charles A., and Pfafrey, T. (2003): Risk Averse Behavior in Generalized Matching Pennies Games, *Games and Economic Behavior* 45, 97 – 113.
- Güth, R., Schmittberger, R., and Schwarze, B. (1982): An Experimental Analysis of Ultimatum Bargaining, *Journal of Economic Behavior and Organization* 3, 367 – 388.
- Guyer, M. J., and Rapoport, A. (1972): 2×2 – Games Played Once, *Journal of Conflict Resolution* 16, 409 – 431.
- Harsanyi, J., and Selten, R. (1988): A General Theory of Equilibrium Selection in Games, MIT Press.
- Huettel, S. A., and Lockhead, G. (2000): Psychologically Rational Choice: Selection between Alternatives in a Multiple-Equilibrium Game, *Journal of Cognitive Systems Research* 1, 143 – 160.
- Ledyard, J.O. (1995): Public Goods: A Survey of Experimental Research” in Kagel, J., and Roth, A. (eds.), *Handbook of Experimental Economics*, Princeton University Press, p.111-194.
- McKelvey, R.D., and Pfafrey, T.R. (1995): Quantal Response Equilibria for Normal Form Games, *Games and Economic Behavior* 10, 6 – 38.
- Milgrom, P. and Roberts, J. (1990): Rationalizability, Learning, and Equilibrium in Games with Strategic Complementarities, *Econometrica* 58, 1255 – 1277.
- Monderer, D. and Shapley, L.S. (1996): Potential Games, *Games and Economic Behavior* 14, 124-143.
- Ochs, J.(1995): Coordination Problems, in Kagel, J., and Roth, A. (eds.), *Handbook of Experimental Economics*, Princeton University Press, 195 – 249.
- Ochs, J. and Roth, A. E. (1989): An Experimental Study of Sequential Bargaining, *American Economic Review* 79, 355 – 84.
- Samuelson, L. (2005): Economic Theory and Experimental Economics, *Journal of Economic Literature* 43, 65-107.
- Schmitt, D., Schupp, R., and Walker, J. (2003): Playing Safe in Coordina-

- tion Games: The Role of Risk Dominance, Payoff Dominance, and History of Play, *Games and Economic Behavior* 42, 281 – 299.
- Topkis, D.M. (1978), "Minimizing a Submodular Function on a Lattice", *Operations Research* 26, 305 – 321.
- Van Huyck, J.B., Battalio, R.C., Beil, R.O. (1990): Tacit Coordination games, strategic uncertainty, and coordination failure, *American Economic Review* 80, 234 – 248.
- Vives, X. (1990): Nash Equilibrium with Strategic Complementarities, *Journal of Mathematical Economics* 19, 305 – 321.
- Vives, X. (2005): Complementarities and games: New developments, *Journal of Economic Literature* 43, 437 – 479.

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