



UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

ECONOMIC ESSAYS ON BARGAINING AND COOPETITION

DISSERTATION

ZUR ERLANGUNG DES AKADEMISCHEN GRADES
DOCTOR RERUM POLITICARUM

AN DER
FAKULTÄT FÜR WIRTSCHAFTS- UND
SOZIALWISSENSCHAFTEN
DER RUPRECHT-KARLS-UNIVERSITÄT HEIDELBERG

VORGELEGT VON

David Johannes Piazolo

HEIDELBERG, OKTOBER 2024

Acknowledgements

Most importantly, I would like to thank my supervisor and co-author, Christoph Vanberg. Your unwavering support, insightful guidance, and constructive feedback have been crucial in shaping my development as a researcher. I deeply appreciate your open-door policy and the fact that you always made time for me. Working with you has not only been a very enriching but also a very much enjoyable experience. For me personally, there could not have been a better supervisor.

In addition, I am deeply grateful to Jörg Oechssler, who served as the second referee for this dissertation. My research has benefited from your profound insights on game-theoretic concepts, as well as from your valuable ideas and constructive feedback.

This thesis profited greatly from working together with my co-author, Julian Matthes. Working with you was so much fun. To borrow from the language of our model, there was never any coordination failure, even though we might have been equally diversified. For those interested in more insights on this line of thinking, feel free to turn to Chapter 4.

Also, I would like to thank all my other colleagues at AWI for the insightful discussions and coffee breaks. Special thanks go to Freya Schadt and my daily lunch and sports partners, also known as friends: Anna, Christoph, Felix, Matthias, Robin, Nils, and Fabian.

My deepest gratitude goes to my family. The constant love and support of my parents, Carola and Marc, has made this journey so much easier. Thanks to my dad for all the valuable feedback along the way, including the four papers this dissertation consists of. To my brothers, Simon, Lorenz, and Elias — being around you is always a joy. Thank you all for creating such a wonderful home.

Lastly, I would like to dedicate this thesis to my beloved wife, Marieke. As always, this has been a team effort, and I cannot imagine a better team member. Your endless support, love, and belief in me mean the world.

Contents

Introduction	1
1 Multilateral bargaining with private information: Theory	9
1.1 Introduction	10
1.2 Related literature	12
1.3 Bargaining game and equilibrium concept	14
1.4 Majority rule	17
1.4.1 Period 2 voting and proposals	17
1.4.2 Continuation values and beliefs	19
1.4.3 Period 1 voting	20
1.4.4 Period 1 proposal	26
1.5 Unanimity rule	27
1.5.1 Period 2 voting and proposals	28
1.5.2 Continuation values and beliefs	29
1.5.3 Period 1 voting	30
1.5.4 Period 1 proposal	35
1.6 Unanimity vs. majority rule	37
1.6.1 Period 1 “prices”	37
1.6.2 Probability of breakdown	39
1.7 Discussion	41
Appendix	45
1.A Majority rule	45
1.A.1 Period 2 proposal (majority rule)	45
1.A.2 Period 1 voting (majority rule)	45

CONTENTS

1.A.3	Proof of Lemma 4	54
1.B	Unanimity rule	57
1.B.1	Period 2 proposal (unanimity rule)	57
1.B.2	Period 1 voting (unanimity rule)	57
1.B.3	Selection of voting equilibria (unanimity rule)	69
2	Multilateral bargaining with private information: Experiment	75
2.1	Introduction	76
2.2	Literature	78
2.3	Theory	80
2.3.1	Equilibrium under public information	81
2.3.2	Equilibrium under private information	83
2.4	Experiment	86
2.4.1	Hypotheses	86
2.4.2	Experimental design	91
2.5	Results	94
2.5.1	Unanimity rule	94
2.5.2	Majority rule	97
2.5.3	Unanimity vs. majority rule	99
2.6	An ex-post approach to explain observed deviations	105
2.7	Concluding remarks	109
	Appendix	113
2.A	Experiment	113
2.A.1	Experimental design	113
2.A.2	Predictions	114
2.A.3	Proposer behavior	116
2.A.4	Responder behavior	120

2.A.5	Agreement probabilities	132
2.B	Adjusted model	134
2.B.1	Setup	134
2.B.2	Unanimity rule: A pivotal proposal	135
2.B.3	Majority rule: A Period 1 MWC	137
3	Multilateral bargaining with private information: (Un)reliability	139
3.1	Introduction	140
3.2	Literature	143
3.3	Model	144
3.4	Reliable parties ($p=0$)	149
3.4.1	Majority rule	149
3.4.2	Unanimity rule	152
3.5	Unreliable parties ($p > 0$)	154
3.5.1	Majority rule	154
3.5.2	Unanimity rule	157
3.6	A comparison of the voting rules: Main results	159
3.7	Extensions and further insights	163
3.7.1	Larger coalitions	163
3.7.2	Asymmetric beliefs about the future	165
3.8	Concluding remarks	165
Appendix		169
3.A	Proofs of main propositions	169
3.A.1	Proof of Proposition 6	169
3.A.2	Proof of Proposition 7	171
3.A.3	Proof of Proposition 8	171
3.B	Additional results	173

CONTENTS

3.B.1	The responder's price	174
3.B.2	The probability of an overall breakdown	174
3.B.3	Welfare implications	175
3.C	Extensions	176
3.C.1	Larger coalitions in a finite player game	176
3.C.2	The continuation probability delta	179
4	Theory and evidence on coopetition in road cycling	181
4.1	Introduction	182
4.2	Model	190
4.2.1	Actions and strategies	191
4.2.2	Payoff function	192
4.3	Illustration of main principles	194
4.3.1	Teammates in a group: How to coordinate a chase	195
4.3.2	Teammates across groups: Creating free-riding opportunities	199
4.4	General theoretical results	203
4.5	Data and empirical strategy	206
4.5.1	Race results data	208
4.5.2	Data processing	209
4.5.3	Individual rider data	209
4.5.4	Group characteristics	210
4.5.5	Hypotheses	211
4.6	Results	213
4.6.1	Comparing groups	213
4.6.2	Impact of group characteristics on win probabilities	215
4.7	Conclusion	219

Appendix	225
4.A Case study: The strategic benefits of having multiple leaders in road cycling	
races	225
4.A.1 Who controls a race?	226
4.A.2 The strategic benefit of multiple leaders	227
4.A.3 The crucial role of beliefs	228
4.A.4 How to use multiple leaders in a stage race	228
4.B Theory	231
4.B.1 Position updating	231
4.B.2 Payoff matrices	231
4.B.3 Proof of Proposition 1	233
4.B.4 Proof of Proposition 2	235
4.C Empirical results	236
4.C.1 Summary statistics	236
4.C.2 In-race data	236
4.C.3 Additional analyses	238
4.C.4 Logistic regressions	244
4.C.5 One-day races	245
Bibliography	248

List of Figures

1.1	Period 2 proposals (majority rule)	18
1.2	Equilibria following Period 1 proposal (majority rule)	25
1.3	Period 2 proposals (unanimity rule)	28
1.4	Equilibria following Period 1 proposal (unanimity rule)	35
1.5	Responders' prices	40
2.1	Mean Period 1 agreement probabilities	100
2.2	Mean Period 2 agreement probabilities	101
2.3	Period 1 proposals (private information)	104
2.4	Voting decision in Period 1	113
2.5	Period 1 proposals (public information, both high)	116
2.6	Period 1 proposals (public information, high and low)	117
2.7	Period 1 proposals (public information, both low)	118
2.8	Voting on Period 1 proposals (private information, high type)	124
2.9	Voting on Period 1 proposals (private information, low type)	125
2.10	Voting on Period 1 proposals (public information, high type, other is high)	126
2.11	Voting on Period 1 proposals (public information, high type, other is low)	127
2.12	Voting on Period 1 proposals (public information, low type, other is high)	128
2.13	Voting on Period 1 proposals (public information, low type, other is low)	129
4.1	Coordinating a chase (A)	195
4.2	Coordinating a chase (B)	197
4.3	Teammates across groups (A)	199
4.4	Teammates across groups (B)	200
4.5	A hypothetical penultimate period	202

LIST OF FIGURES

4.6	Controlling the race	226
4.7	How (not) to use your teammates	229

List of Tables

2.1	Voting predictions when pivotal (unanimity rule, low type)	87
2.2	Voting predictions when pivotal (majority rule, high type)	89
2.3	Between subject treatment parameters	92
2.4	Share of pivotal responders voting Yes (unanimity rule, low type)	94
2.5	Linear regression model: Period 2 offers (unanimity rule)	97
2.6	Share of pivotal responders voting Yes (majority rule, high type)	98
2.7	Period 2 proposals after a MWC in Period 1 has been rejected	98
2.8	Share of pivotal responders voting Yes (private information, high delta) . .	100
2.9	Categorized messages (unanimity rule, private information)	102
2.10	Adjusted responders' Period 1 prices	107
2.11	Period 1 prices for pivotal responders (unanimity rule)	114
2.12	Period 1 prices for pivotal responders (majority rule)	114
2.13	Voting predictions on exogenous Period 1 offers when pivotal	115
2.14	Voting predictions on exogenous proposals that treat both equally	115
2.15	Period 2 proposals (unanimity rule)	119
2.16	Share of pivotal responders voting Yes on exogenous Period 1 proposals . .	120
2.17	Share of responders voting Yes on exogenous proposals that treat both equally	121
2.18	Wilcoxon rank-sum test: Low vs. high delta (unanimity rule, low type) . .	121
2.19	Two-proportion z-test: Low vs. high delta (unanimity rule, low type) . . .	121
2.20	Wilcoxon signed-rank test: Private vs. public information (unanimity rule, low type)	122
2.21	Generalized Estimated Equations: Private vs. public information (unanim- ity rule, low type)	122

LIST OF TABLES

2.22 Wilcoxon rank-sum test: Unanimity vs. majority rule (private information, high delta)	122
2.23 Two-proportion z-test: Unanimity vs. majority rule (private information, high delta)	122
2.24 Proposing a MWC in Period 1	130
2.25 Voting Yes on a MWC in Period 1	131
2.26 Two-proportion z-test: More messages under the following voting rule . . .	132
2.27 Period 1 passage probabilities of the endogenous proposal	132
2.28 Period 2 passage probabilities	133
3.1 The bargaining process	146
4.1 Actions	191
4.2 Situation 1.b - payoff matrix	196
4.3 Summary of possible setups in the last period	201
4.4 Asymmetry in losing versus winning groups	214
4.5 Linear probability model: Being part of a winning group (with 3 to 6 riders)	215
4.6 Linear probability model: Finishing in Group 1	216
4.7 Linear probability model: Winning the race from Group 1	218
4.8 Payoff matrices of the discussed situations	232
4.9 Summary statistics of non-dummies	236
4.10 Mean occurrence of dummies	236
4.11 Linear probability model: Finishing in Group 1 - in-race data	237
4.12 Linear probability model: Winning the race from Group 1 - in-race data . .	238
4.13 Linear probability model: Finishing in Group 1 - fewer Stars	239
4.14 Linear probability model: Winning the race from Group 1 - fewer Stars . .	240
4.15 Linear probability model: Finishing in Group 1 - smaller groups	241
4.16 Linear probability model: Winning the race from Group 1 - smaller groups	242

4.17	Linear probability model: Winning the race from Group 1 - continued . . .	243
4.18	Logistic probability model: Finishing in Group 1	244
4.19	Logistic probability model: Winning the race from Group 1	245
4.20	Summary statistics of non-dummies	245
4.21	Mean occurrence of dummies	246
4.22	Linear probability model: Finishing in Group 1 - one-day races	246
4.23	Linear probability model: Winning the race from Group 1 - one-day races .	247

Introduction

“The art of negotiation is perhaps what most deeply distinguishes man from the animals, and it is this art and this will to negotiate that has brought man forward, elevated him beyond the animals.”

- Harry Martinson, author and Nobel Prize winner

The ability to negotiate, or to bargain, is a defining characteristic of humankind, crucial in virtually every situation where the interests of two or more parties may conflict but also overlap. Negotiation is essential in diverse contexts, from social and personal relationships to business and corporate settings, or political and legislative processes. However, nowhere is the importance of bargaining more evident than in politics, as acknowledged by many politicians around the world.

“Let us never negotiate out of fear. But let us never fear to negotiate.”

- John F. Kennedy

Indeed, the resolution of nearly all pressing global issues — be it international conflicts, economic development, or the climate crisis — hinges on successful bargaining. Wars are most likely to end and best to prevent when the involved parties come together to negotiate a peace agreement. Economies thrive when nations strike trade deals and collaborate. The fight against the climate crisis can only succeed through coordinated international effort and cooperation.

This thesis seeks to illuminate two types of situations where multiple parties with conflicting interests come together to negotiate an outcome they may mutually benefit from. The first three chapters focus on a three-party bargaining game. They analyze

the impact of different voting rules, private information, and a party's unreliability on the bargaining behavior of the various parties involved. The second type of situation, discussed in Chapter 4, addresses coopetition — a setup where parties simultaneously cooperate and compete to create value. While cooperation between competing parties is crucial for reaching agreements in bargaining, this chapter shifts attention away from the bargaining process itself. Instead, it explores how parties can strategically position themselves before negotiations begin, helping them to secure a more favorable position once negotiations are underway.

Before addressing the specifics of each chapter, it is important to clarify the framework I envision when discussing bargaining. Bargaining has been a central topic in economics for over a century. Edgeworth (1881) was among the first to address this issue, describing it as the most fundamental problem in economics. In his seminal work, Nash (1950) defined a two-person bargaining situation as one where “two individuals have the opportunity to collaborate for mutual benefit in more than one way”.

Rubinstein (1982) further conceptualized bargaining as the process of dividing a pie (or a dollar). There, all players are impatient, aim to maximize their share, and take turns making proposals. In his bilateral problem with perfect information, the equilibrium predicts that the first proposal is accepted with certainty.

In contrast to such bilateral problems, the focus in this dissertation lies on multilateral and legislative bargaining situations, i.e., with more than two parties being involved and where any agreement is binding for all parties. By extending the bilateral model of Rubinstein (1982) under unanimity rule to a multilateral model under majority rule, Baron and Ferejohn (1989) established the most widely used formal model for studying multilateral bargaining. In the Baron-Ferejohn bargaining model, a group member is randomly selected to propose a division of the pie. The proposed division is then subjected to a majority vote by all members. If the proposal is rejected, another member is randomly chosen to make a new proposal, and this process continues until a budget split gains approval by the

required number of parties. The essentially unique stationary subgame perfect equilibrium of this game results in an efficient outcome, granting the proposer significant bargaining power and allowing them to secure a substantially larger share of resources compared to other members.

This model has served as the foundation for numerous further studies, with applications and theoretical extensions both within and beyond political science. For a comprehensive survey of the theoretical literature on legislative and multilateral bargaining, see Eraslan and Evdokimov (2019). In this context, the Baron-Ferejohn model offers a valuable framework for exploring the effects of different voting rules. A key question in Public Choice theory is determining which decision rule is most appropriate for collective bargaining. Analyzing the characteristics of various “q-majority rules”, where q represents the number of individuals required to consent for a decision to be enacted, is therefore crucial. For instance, in the European Council, voting rules differ across policy areas, and there is an ongoing debate about expanding the use of the “qualified majority rule” in place of unanimity (Schuette (2019)). In their seminal work, Buchanan and Tullock (1965) offer a foundational analysis of unanimity and majority rule. Specifically, they demonstrate that a more pronounced fear of exclusion under majority rule (which they assume) diminishes the responders’ incentives to adopt a “tough” bargaining stance.

In many bargaining situations, parties possess private information regarding their willingness to reach an agreement. This may reflect the value of outside options or personal benefits derived from reaching a consensus. The introduction of private information into formal bargaining theory was pioneered by Fudenberg and Tirole (1983) in a bilateral model. However, research on multilateral bargaining involving private information remains relatively scarce. The first three chapters of this dissertation aim to address this gap by exploring how private information influences the differences between unanimous and non-unanimous voting rules.

In Chapter 1, we find that the presence of private information intensifies the distinctions

between voting rules. Chapter 2 empirically tests the predictions derived in Chapter 1 through a laboratory experiment. This contributes to the extensive body of experimental research on bargaining. A meta-analysis by Baranski and Morton (2022) reviews all the experimental work conducted on this topic, highlighting significant discrepancies between theoretical predictions and experimental results. Chapter 2 confirms these discrepancies particularly when majority rule is applied. Chapter 3 explores a related scenario, examining the effects of one of the bargaining parties being unreliable.

In a slightly different vein, Chapter 4 examines a coopetition problem in the context of road cycling. Alongside a theoretical analysis, it incorporates empirical data from professional road cycling races. This is a notable advantage compared to classical bargaining problems, where field data often is scarce. By utilizing real-world data from a bargaining-related context, this chapter adds an innovative empirical dimension not only to my thesis but also to the bargaining and coopetition literature in general. The use of sports data in economics has a long-standing tradition, aptly captured by a quote from Nobel Prize Laureate Daniel Kahneman (2008): “Studying sport is a great idea, because people make many decisions that matter enormously to them under standard conditions.”

A common theme of all four chapters lies in their exploration of how outside options affect group dynamics in various situations, ranging from the classic “Divide-the-Dollar” bargaining game to the specific coopetition problem discussed in Chapter 4. Chapters 1, 2, and 3 demonstrate that if unanimity rule is applied in bargaining scenarios, having a strong outside option proves advantageous. In situations involving private information, players even have incentives to mimic the behavior of those with better outside options, deceiving the proposer to secure larger shares in future bargaining rounds. Conversely, under majority voting, a strong outside option can be detrimental in the bargaining process due to a thereby increased risk of being excluded from a winning coalition. However, this theoretically predicted negative impact appears significantly diminished in experimental settings (see Chapter 2) and in case bargaining parties might be unreliable (see Chapter

3). Chapter 4 extends the positive impact of a strong outside option into a different context. In the underlying setup, an external option, such as having stakes in different groups, provides a team with greater opportunities for free-riding within their group's coopetition problem.

In the remainder of the Introduction, I will provide an overview of the approaches and key findings of the various chapters.

Chapter 1

In this chapter, jointly written with Christoph Vanberg, we theoretically explore a three-person, two-period bargaining game involving private information. A fixed proposer aims to secure agreement on a proposal under either majority or unanimity rule. If the first-period proposal is rejected, the game may end immediately with an exogenously determined breakdown probability. The two responders have privately known breakdown payoffs and vote “yes” or “no” on each proposal. We fully characterize and depict all Bayesian equilibria in stagewise undominated strategies.

Our main finding is that under unanimity rule, responders are incentivized to vote “no” on the initial proposal to signal that they possess a large breakdown payoff. Under majority rule, no such incentive exists. This difference arises because being perceived as a “high breakdown value type” offers an advantage under unanimity rule but poses a disadvantage under majority rule.

Under unanimity rule, the proposer must include even the most expensive responder in her coalition for an agreement to be reached. In contrast, under majority rule, the proposer will exclude the responder that is perceived as most expensive from her winning coalition. Consequently, responders are “more expensive” under unanimity rule, making inefficient disagreements more likely. These results not only validate intuitions that have been informally suggested but also provide deeper insights into the underlying incentives and their implications for optimal bargaining behavior when private information is involved.

Chapter 2

Chapter 2, also co-authored with Christoph Vanberg, empirically tests the key theoretical predictions from the previous chapter through a laboratory experiment. We manipulate the voting rule (majority versus unanimity) and the continuation probability after a Period 1 proposal failure ($\delta = 1/6$ versus $\delta = 5/6$) between subjects. Additionally, the experiment incorporates within-subject variation in the available information about responders' breakdown values, with these values being either privately known to the individual responder or publicly disclosed.

Our findings largely confirm the main equilibrium predictions under unanimity rule. Specifically, we observe that responders become more “expensive” when the continuation probability is high and when breakdown values are of private information. This suggests that under unanimity rule, subjects perceive a positive signaling incentive to vote “no”, leading to higher responders' prices and lower agreement probabilities when breakdown values are of private information than when they are publicly observable. However, the experimental results under majority rule are less consistent with theoretical predictions. Fewer minimum winning coalitions are proposed and responders' prices are larger than expected. Thus, the anticipated fear of exclusion following a “no” vote is lower than what theory predicts. This suggests that factors such as other-regarding preferences, including inequality aversion, may influence behavior.

Chapter 3

Chapter 3 is single-authored and inspired by the “German Vote”. This term recently emerged in the EU Parliament, referring to Germany's reluctance to vote in favor of various projects, even after signaling support during the bargaining process. In this paper, I specifically examine the strategic effects of varying *unreliability* of bargaining partners under both unanimous and non-unanimous voting rules. Unreliability can arise from several factors. On the international stage, situations such as impending domestic elections or

internal disagreements within ruling coalitions can make a negotiating country unreliable.

The focus of my analysis is on the effect of one responder's unreliability on the other responder's voting behavior. To explore this, I make a slight adjustment to the theoretical bargaining model presented in Chapter 1. In this modified version, the responder of interest continues to have private information about their valuation of the agreement, while the other responder is modeled as an unreliable "robot" type. This robot type is assumed to vote "yes" whenever offered a publicly known fixed share but may still vote "no" with some probability, which defines their level of *unreliability*.

The analysis offers three main contributions. First, the model simplifies and confirms the key theoretical findings of Chapter 1. Second, it shows that under both voting rules, an increase in one responder's unreliability negatively affects the other responder's willingness to vote "yes". This makes it increasingly challenging to reach efficient agreements. Third, under majority rule, the presence of unreliable parties can lead to the inclusion of more parties in the winning coalition.¹

Chapter 4

Chapter 4, jointly written with Julian Matthes, studies a coopetition problem. In particular, the problem involves competition between two groups of individuals with team affiliations. In addition, within each group, there is a coopetition problem to outperform the opposing group. We provide a detailed model based on road cycling races, which naturally feature this strategic framework.

Our theoretical analysis reveals that groups tend to cooperate more effectively when they are composed of riders with asymmetric levels of "strength".² Also, adding teammates to a competing group consistently proves advantageous. When members have stakes

¹This is demonstrated through an extension of the model. Interestingly, this finding aligns with the experimental results under majority rule from Chapter 2, indicating a reduced fear of exclusion and thus higher responder prices.

²We will differentiate between individual strength and team strength. Asymmetry in both of these types of strengths leads to more effective cooperation.

in a competing group, it creates an external threat to other teams within the same group, pressuring those members to take the lead and exert maximum effort. As a result, diversification offers a strategic benefit by allowing for more extensive free-riding.

By analyzing data from over 40 seasons of professional road cycling races, we find empirical evidence supporting our theoretical findings. Specifically, having a teammate in a group behind positively impacts the probability of winning. This suggests that it is indeed strategically advantageous to place riders in competing groups, i.e., to be diversified. Beyond road cycling, we also explore applications in industrial and workplace organization.

Chapter 1

Legislative bargaining with private information: A comparison of majority and unanimity rule¹

Abstract

We present a three-person, two-period bargaining game with private information. A single proposer is seeking to secure agreement to a proposal under either majority or unanimity rule. If the first period proposal fails, the game ends immediately with an exogenously given “breakdown” probability. Two responders have privately known disagreement payoffs. We characterize Bayesian equilibria in stagewise undominated strategies. Our central result is that responders have a signaling incentive to vote “no” on the first proposal under unanimity rule, whereas no such incentive exists under majority rule. The reason is that being perceived as a “high breakdown value type” is advantageous under unanimity rule, but disadvantageous under majority rule. As a consequence, responders are “more expensive” under unanimity rule and disagreement is more likely. These results confirm intuitions that have been stated informally before and in addition yield deeper insights into the underlying incentives and what they imply for optimal behavior in bargaining with private information.

JEL codes: C78; D72; D82

Keywords: bargaining; voting; unanimity rule; majority rule; private information; signaling

¹This paper is jointly written with Christoph Vanberg and we currently received a revise and resubmit (R&R) decision from *Games and Economic Behavior*.

1.1 Introduction

A fundamental problem in Political Economics is the choice between alternative q -majority rules. In seminal work, Buchanan and Tullock (1965) analyzed this choice from a constitutional perspective. They argued, largely informally, that unanimity rule has the advantage of ensuring that all decisions constitute Pareto improvements, but the disadvantage that it may be associated with large “decision costs”. One reason is that unanimity rule may induce incentives for individuals to “act tough” during negotiations. For example, bargainers may attempt to commit to a tough stance, or *pretend* to be opposed to agreement, hoping to secure concessions from others. Such incentives may be mitigated by the use of less-than-unanimity rules.

Certain aspects of these ideas can be formalized using models involving perfect information (see, e.g., Miettinen and Vanberg (2024)). However, the core intuition as well as its real-world counterpart clearly involve *private information* about individual inclinations to support a proposal. In the presence of private information, the actions taken by individual bargainers may act as (costly) *signals* of their privately known preferences. Our aims in this paper are to model the role of private information explicitly, in order to investigate how such *signaling incentives* are affected by the decision rule being used, and to gain a deeper understanding of what they imply about optimal behavior by proposers and responders in bargaining with private information. In particular, our focus will be on the *signaling value* of voting to support or reject a proposal and how it is affected by the decision rule and the type of proposal being considered.

We analyze a two-period, three-player bargaining game involving a fixed proposer who is trying to secure agreement to a reform, either under majority ($q = 2$) or unanimity ($q = 3$) rule. The two responders can be of two different types, who differ in their willingness to

agree to the reform. This difference is modeled by endowing each responder with a privately known “breakdown value” (either “high” or “low”), which they receive if no agreement is reached. A natural interpretation is that a player’s “breakdown value” reflects the utility of the “status quo” which will prevail if the reform is not implemented. The proposer is endowed with a single monetary unit that she can use to “buy” the responders’ votes, and she has (at most) two chances to get a proposal passed. The monetary unit can be interpreted as a transferable surplus that will be generated by the proposed change to the “status quo”. Breakdown occurs with some probability if the first proposal fails, and for sure if the second proposal fails. (The game is formally defined in Section 1.3.) Despite its simplicity, this game is very rich in strategic complexity. This is due to the endogenous signaling effects associated with voting behavior. Our equilibrium concept is Perfect Bayesian Equilibrium in stagewise undominated strategies.

A key insight emerging from the analysis is that responders consider two types of incentives when choosing how to vote on a given proposal. The first relates to the influence of their vote on the fate of the proposal under consideration. The second pertains to its effect on the proposer’s belief about their type. Under some circumstances, these incentives may point in opposite directions. That is, a responder may prefer that a given proposal passes, but fear that voting “yes” will reveal something about their type which they would rather conceal. The relative importance of these considerations depends on the probability with which the responder’s vote is pivotal. The strategic implications are quite intricate, and play out quite differently under majority and unanimity rule.

Our main results are as follows. Under both majority and unanimity rule, voting “no” on certain first period proposals constitutes a *signal* that a responder is a “high” type. Under unanimity rule, this signaling effect benefits the responder in the sense that it causes the proposer to make a more favorable offer to him in Period 2. We refer to this as a positive “signaling value” from rejection. Under majority rule, by contrast, the signaling value is generally *negative*, because responders who vote “no” can be excluded from subsequent

coalitions (and it is in the interest of the proposer to do so). As a consequence of this difference in signaling incentives, responders are “more expensive” (in a sense that will be made more precise) under unanimity rule. The set of proposals that can pass in Period 1 is significantly larger under majority rule, not just because agreement requires fewer “yes”-votes, but also because responders are more willing to vote “yes” when allocated a given share. Under majority rule, agreement in the first period is more likely in the sense that, for a wide parameter range, the proposer will find it optimal to immediately secure one responder’s agreement, while under unanimity rule, she prefers to make a proposal that fails with positive probability.

Overall, these results lend support to the intuitive argument that unanimity rule induces “tough” bargaining behavior and is associated with greater delay. In addition, our analysis provides a deeper understanding of the signaling incentives in multilateral bargaining as well as implications for optimal behavior in the presence of private information. The rest of the paper is organized as follows. Section 1.2 discusses related literature. Section 1.3 presents our game and equilibrium concept. Sections 1.4 and 1.5 present analyses of majority and unanimity rule, respectively. Section 1.6 compares the results in order to make precise our conclusions that unanimity rule is associated with higher “prices” and more delay. Section 1.7 concludes and discusses the additional strategic insights generated by the analysis. Proofs are presented in the Appendix.

1.2 Related literature

Our contribution fits broadly into a literature on q -majority rules in multilateral bargaining games with complete information. More specifically, there is a connection to models that involve any sort of heterogeneity with respect to individual players’ willingness to agree. For example, consider a standard Baron and Ferejohn (1989) bargaining game with complete information and heterogeneous discount factors. There, a larger discount factor implies a “tougher” bargaining stance and a higher “price” for a player’s vote. It is folk knowledge

that this is advantageous under unanimity rule but not under majority rule. That is, a player’s expected payoff is increasing in his discount factor under unanimity rule, but non-monotone (and eventually decreasing) under less-than-unanimity rules. Miller et al. (2018) consider a modified Baron-Ferejohn game with *commonly known* breakdown values and show that a larger breakdown value is advantageous under unanimity rule, but can be bad under majority rule because “expensive” players are excluded from winning coalitions. These results are *suggestive* of the idea that, when the source of heterogeneity is private information, players would like to *signal* that they are “tough” (e.g., have a large discount factor or breakdown value) under unanimity rule, while they would not like to do so under less-than-unanimity rules.

The literature on multilateral bargaining with private information is scarce. Tsai and Yang (2010b) investigate a three-player, three-period Baron-Ferejohn game with private information about discount factors. They show that under majority rule, equilibrium might involve delay and oversized coalitions. An important difference between our paper and Tsai and Yang (2010b) is that we also investigate unanimity rule, allowing us to discuss the different signaling incentives associated with different voting rules.²

Chen and Eraslan (2014) investigate a three-player majoritarian bargaining game over an ideological and distributive decision with private information about ideological intensities. As in our setting, a single proposer is seeking the support of either one (majority rule) or both (unanimity rule) responders, and she is unsure as to how much each responder must be paid in order to secure his vote. Unlike in our setting, the proposer can make only one proposal, so there is no room for costly signaling by voting “no”. Instead, Chen and Eraslan (2014) consider cheap talk communication prior to the proposal stage. They investigate the circumstances under which cheap talk communication can credibly convey information. A central finding is that competition between the two responders may result

²Tsai (2009) discusses a similar game under both majority and unanimity rule, deriving conditions for the existence of separating and pooling equilibria. Our model differs in several respects, and we provide a significantly more comprehensive equilibrium analysis.

in less information conveyed in equilibrium and may make the proposer worse off as compared to unanimity rule (and only one responder). (Chen and Eraslan (2013) investigate a similar model in which the responders’ ideal points are private information.)

Our paper is also related to the literature on reputational bargaining. Abreu and Gul (2000) investigate a bilateral bargaining game in which players may, with some probability, be of an “obstinate” type that is committed to claim a certain share of the pie. They show that the presence of such types creates incentives for “rational” types to imitate them, i.e., to “act tough”. Ma (2023) applies this idea to a multilateral *majoritarian* bargaining game and finds that the threat of exclusion under majority rule removes this incentive to act “tough”.

Finally, our paper is also related to the literature in *bilateral* bargaining with private information. Naturally, these models only consider unanimity rule ($q = n = 2$). The paper that is most relevant to our analysis is Fudenberg and Tirole (1983), who investigate a two-person, two-period bargaining game in which a seller is looking to sell an object to a buyer whose valuation is privately known. The seller has two chances to make a proposal (suggested price). As in their model, equilibrium strategies in our context necessarily involve buyers *mixing* between accepting and rejecting certain proposals.

1.3 Bargaining game and equilibrium concept

The bargaining game The game involves three players, a Proposer (P, she) and two responders (R1 and R2, he). The game lasts two periods $t = 1, 2$. Each period consists of a *proposal stage* and a *voting stage*. During the proposal stage, P makes a *proposal* $x_t = (x_{1t}, x_{2t}) \in X$, where $X = \{(x_1, x_2) : x_i \geq 0, x_1 + x_2 \leq 1\}$. Then R1 and R2 simultaneously *vote* either “yes” (Y) or “no” (N), denoted $v_{it} \in \{Y, N\}$. If q responders vote Y , the proposal *passes*. In this case the payoffs are $\pi_P = 1 - x_{1t} - x_{2t}$ and $\pi_i = x_{it}$ for $i = 1, 2$. If fewer than q responders vote Y , the proposal *fails*. If the Period 1 proposal fails, the game ends in “breakdown” with probability $(1 - \delta)$ and otherwise continues to Period 2.

If the Period 2 proposal fails, the game ends in breakdown. In case of breakdown in either period, P's payoff is $\pi_P = 0$ and Ri's payoff is $\pi_i = b_i$, where b_i denotes an exogenously given "breakdown value".

Responders can be of two types, which we denote $T \in \{L, H\}$ ("low", "high"). The "low" type's breakdown value is denoted $l > 0$, and the "high" type's is $h > l$. Thus, the high type is more strongly opposed to agreement, and presumably requires a larger compensation in return for a "yes" vote. For some of what follows, it will be convenient to define $\tau = h - l$ to be the difference in high and low breakdown values. Types are independently drawn and equally likely ex ante.

Throughout the analysis, we assume that agreement is *efficient* even in the "worst case" where both responders are of type H . This requires $h < \frac{1}{2}$ (implying $\tau < \frac{1-2l}{2}$). This assumption implies that P is willing to offer both responders h in Period 2 if she is sufficiently sure that they are both of type H .³ Note that payoffs are not discounted, but delay is costly due to the probability of breakdown.

Strategies A pure strategy for P specifies a Period 1 proposal $x_1 = (x_{11}, x_{21})$ as well as a Period 2 proposal following any history that leads to Period 2. Such a history consists of a Period 1 proposal and voting patterns $v_1 = (v_{11}, v_{21}) \in \{Y, N\}^2$, where v_{i1} denotes Responder i 's vote on the first proposal. If $s \in X \times \{Y, N\}^2$ is a history leading to failure of the first proposal, we denote P's ensuing Period 2 proposal by $x_2(s)$. For example, $x_2((\frac{1}{2}, 0), (N, N))$ is the proposal made following a history where $(\frac{1}{2}, 0)$ was proposed in Period 1 and both responders voted N.

A strategy for Responder i specifies type-dependent acceptance probabilities $\mu_{it}^T(x) \in [0, 1]$ for all $x \in X$ and $t = 1, 2$.⁴ For some parts of the analysis, we will drop the dependence

³Admittedly, this assumption is restrictive, as it precludes an analysis of the substantively interesting case where agreement may be inefficient. However, as will become clear, the analysis is quite involved and involves several case distinctions even under this simplifying assumption. Thus the more general case is left for future research.

⁴In principle, Period 2 acceptance probabilities could depend on elements of the history other than the proposal x_2 . However, elimination of weakly dominated strategies implies that in equilibrium they will not.

on both t and x (when both are considered fixed), and write Ri's acceptance probabilities as $\mu_i = (\mu_i^L, \mu_i^H)$. For example, $\mu_1 = (1, 0)$ means that R1 votes Y if his breakdown value is low and N if his breakdown value is high.

Equilibrium concept Our equilibrium concept is perfect Bayesian equilibrium in stage-wise undominated strategies, with an intuitive restriction on off-path beliefs. In the following definition, a “history” is a complete description of all proposals and votes that occur before an information set at which a given player is called upon to take an action.

Definition 1. A strategy profile $(\sigma_1, \sigma_2, \sigma_P)$ and (common) belief system ω is an *equilibrium* if the action specified by each σ_i at each history maximizes i 's payoff given beliefs at that history and in addition, the following criteria are met:

1. In all stages of the game involving simultaneous actions, strategies place zero probability on actions which are weakly dominated given continuation payoffs implied by equilibrium play in later stages.⁵
2. Beliefs are formed using Bayes' rule whenever possible.
3. Off-path beliefs satisfy:
 - (a) If receiver i votes N following a Period 1 proposal at which his equilibrium strategy is $\mu_i = (1, 1)$ (i.e., following an unexpected N-vote), beliefs assign probability 1 to that responder being a high type.
 - (b) If receiver i votes Y following a Period 1 proposal at which his equilibrium strategy is $\mu_i = (0, 0)$ (i.e., following an unexpected Y-vote), beliefs assign probability 0 to that responder being a high type.

It is therefore without loss of generality to write acceptance probabilities as functions of x and T only.

⁵The term “stage undominatedness” was first introduced by Baron and Kalai (1993).

Outline of analysis We begin by providing a comprehensive analysis of all “continuation equilibria” following any first round proposal. It will turn out that many proposals admit multiple continuation equilibria. The reason is that voting in Period 1 determines Period 2 beliefs, which in turn determine the Period 2 proposal, inducing expectations that rationalize the Period 1 voting patterns in a self fulfilling loop.

To deal with this multiplicity, we focus on those continuation equilibria which the proposer most prefers. This approach can be motivated by imagining the proposer making a self-enforcing announcement as to his intentions in the event of proposal failure. Finally, we identify the optimal first round proposal given this refinement.

1.4 Majority rule

We analyze the game by backward induction, beginning with the final vote (Lemma 1) and the second period proposal.

1.4.1 Period 2 voting and proposals

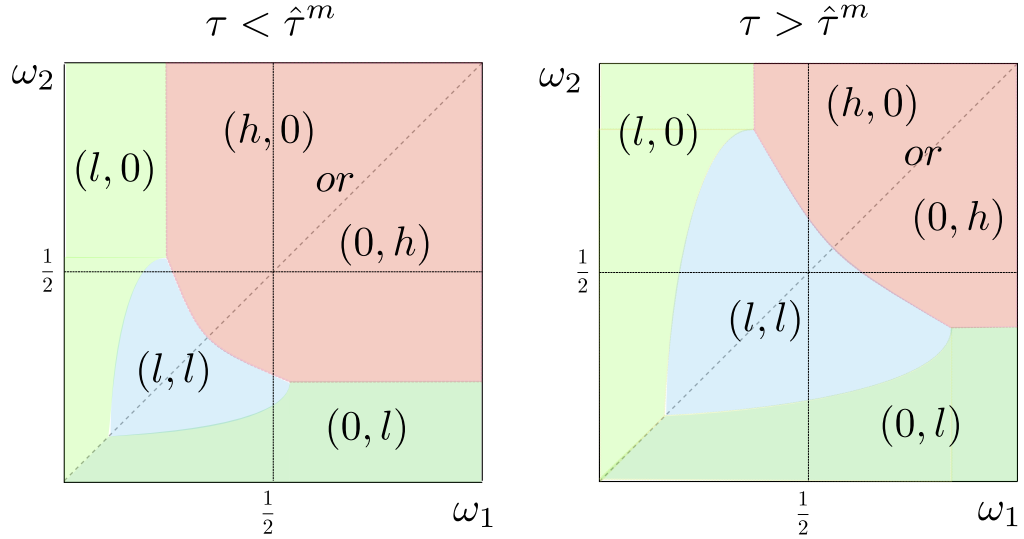
Since the game ends in breakdown if the Period 2 proposal fails, responders compare what they are offered to their breakdown value. Voting insincerely is weakly dominated, and it is without loss of generality to assume that responders vote Y when indifferent. This establishes the following.

Lemma 1. In any equilibrium, responders vote Y in Period 2 iff $x_{i2} \geq b_i$, that is iff they are offered at least their breakdown value.

In Period 2, three types of proposals can conceivably be optimal: Offering h to one responder (and zero to the other) ensures agreement irrespective of their type. Offering l to one responder passes only if the respective responder is a low type. Offering l to both passes if at least one is a low type. Which of these options is optimal will depend on P’s beliefs.

Let $\omega = (\omega_1, \omega_2)$ denote P's belief concerning the probabilities that R1 and R2 are high types. (This will depend on the prior history, but is treated as given at this stage of the analysis.) Figure 1.1 graphically depicts the optimal second period proposal as a function of these beliefs. (See Appendix 1.A.1 for the derivation and functional form.)

Figure 1.1: Period 2 proposals (majority rule)



The figure depicts the Period 2 proposals that P makes given arbitrary beliefs about the responders' types. The horizontal and vertical axes measure the probability that R1 and R2 are of the high type, denoted ω_1 and ω_2 respectively. The left and right panels distinguish the cases where $\tau = h - l$ is greater or smaller than $\hat{\tau}^m \equiv \frac{1+2l}{4}$, which determines the optimal proposal in case $\omega_1 = \omega_2 = \frac{1}{2}$.

Note that the Period 2 proposal is qualitatively affected by whether the difference between the two types' disagreement payoffs, denoted $\tau = h - l$, is small or large. In the following analysis, it will be useful to define a threshold for τ at which this qualitative change occurs. We thus define

$$\hat{\tau}^m \equiv \frac{1 + 2l}{4}.$$

Suppose for a moment that no information is revealed prior to Period 2, so that $\omega =$

$(\frac{1}{2}, \frac{1}{2})$. Then if $\tau < \hat{\tau}^m$, P prefers to offer one responder h in order to make sure that her proposal passes. If $\tau > \hat{\tau}^m$ (i.e., low types are significantly cheaper), P prefers to “gamble” by offering *both* responders l , which passes with probability $\frac{3}{4}$.

1.4.2 Continuation values and beliefs

Let $u_i^T(s)$ denote Ri’s expected utility in Period 2, following a history s , and given his type T . In general, this will depend on the beliefs $\omega = (\omega_1, \omega_2)$ induced by the prior history. For example, if $\tau > \hat{\tau}^m$, then any history that induces beliefs $\omega = (\frac{1}{2}, \frac{1}{2})$ will be followed by the proposal $x_2 = (l, l)$. Therefore, the expected utility of a low type responder at such histories is l (which he receives irrespective of whether the proposal passes or not), while the expected utility of a high type responder is $\frac{l+h}{2}$, as she will vote N and the proposal will pass if and only if the *other* responder is low. Similar reasoning applies for histories inducing other beliefs.⁶

Under majority rule, Period 2 is reached only if *both* responders voted N in Period 1. Then, provided that the Period 1 acceptance probabilities are $(\mu_i^L, \mu_i^H) \neq (1, 1)$, the Period 2 belief about Responder i (given that he voted N) is given by

$$\omega_i^N = \frac{1 - \mu_i^H}{2 - \mu_i^H - \mu_i^L}.$$

In case $(\mu_i^L, \mu_i^H) = (1, 1)$, beliefs following an “unexpected” (off path) N -vote are not determined by Bayes’ rule. As noted above, we assume in this case that $\omega_i = 1$. The following Lemma is stated without proof.

Lemma 2. In any equilibrium and following any history s , Responder i ’s Period 2 expected payoff under majority rule satisfies

- $u_i^T(s) \in [0, h]$ for $T \in \{L, H\}$, and

⁶For some values of ω , P is indifferent between multiple proposals. As a consequence, such ω are consistent with an entire *set* of continuation values consistent with P mixing between those proposals. In addition, *different* histories leading to such a belief may be associated with different continuation values, as P’s proposal (mix) could depend on the history itself.

- $u_i^H(s) \geq u_i^L(s)$.

1.4.3 Period 1 voting

Fix an arbitrary Period 1 proposal (x_1, x_2) , and consider how Responder i may vote on this proposal in what we will call a “continuation equilibrium”. Under majority rule, his vote makes a difference only in the event that the other responder votes N . In this case, voting Y yields x_i , while voting N yields $(1 - \delta)b_i + \delta u_i^T(s)$, where s is the history consisting of proposal (x_1, x_2) and voting pattern (N, N) . Therefore, voting Y is weakly dominated if $x_i < (1 - \delta)b_i + \delta u_i^T(s)$, while voting N is weakly dominated if $x_i > (1 - \delta)b_i + \delta u_i^T(s)$. Then the following lemma follows directly from the fact that $u_i^T(s) \in [0, h]$.

Lemma 3. Let (x_1, x_2) be an arbitrary Period 1 proposal. Then in any equilibrium under majority rule,

- if $x_i \geq h$, then $\mu_i^L = \mu_i^H = 1$,
- if $x_i \geq l + \delta\tau$, then $\mu_i^L = 1$,
- if $x_i < (1 - \delta)h$, then $\mu_i^H = 0$, and
- if $x_i < (1 - \delta)l$, then $\mu_i^L = \mu_i^H = 0$.

Proof. All strict inequalities follow from elimination of weakly dominated strategies. The weak inequalities in cases (1) and (2) are without loss of generality, since an arbitrarily small increment in the offer would guarantee acceptance. $\square$

A Corollary to Lemma 3 is that a low type is always at least as likely to vote Y as a high type, with implications for the signaling consequences of voting N .

Corollary 1. In any equilibrium under majority rule, for any Period 1 proposal (x_1, x_2) , $\mu_i^L \geq \mu_i^H$. In particular,

- if $\mu_i^H > 0$, then $\mu_i^L = 1$, and

- if $\mu_i^L < 1$, then $\mu_i^H = 0$.

Thus $\omega_i^N \geq \frac{1}{2}$.

Proof. Suppose $\mu_i^H > 0$. Then voting Y is not weakly dominated for a high type, which implies that voting N is weakly dominated for the low type. Analogous reasoning establishes the second observation. The last obviously follows from the other two. $\square$

Another implication of Lemma 3 is the following.

Corollary 2. In any equilibrium under majority rule, any Period 1 proposal that allocates at least h to at least one responder passes immediately.

Thus what remains to be analyzed is voting on proposals that allocate *strictly less than* h to *both* responders.

Continuation equilibria when $x_{i1} < h$ for $i = 1, 2$

The following *algorithm* can be used to fully characterize the set of continuation equilibria following any such proposal. The idea behind this algorithm is to begin by positing a pattern of acceptance probabilities and then to back out the set of first round proposals that are consistent with that pattern.

Algorithm to characterize continuation equilibria following Period 1 proposals with $x_{i1} < h$ for $i = 1, 2$ (majority rule)

Let $\mathcal{M}$ be the set of *acceptance probability vectors* $\mu = (\mu_1^L, \mu_1^H, \mu_2^L, \mu_2^H)$ that are consistent with Corollary 1. For each $\mu \in \mathcal{M}$,

1. Identify the *belief vector* $\omega = (\omega_1^N, \omega_2^N)$ induced by a history in which both responders voted N. (Note that this is the only history leading to continuation play.)
2. Characterize the (set of) *continuation value vectors* $u = (u_1^L, u_1^H, u_2^L, u_2^H)$ that are consistent with Period 2 equilibrium play at a history that induces beliefs ω . Call this set $\mathcal{U}(\mu)$. (This will contain a unique vector unless the Proposer is indifferent between multiple proposals at ω .)
3. Identify the (set of) *Period 1 proposals* (x_1, x_2) with the property that there is *some* vector $u \in \mathcal{U}(\mu)$ such that
 - if $\mu_i^T = 0$, then $x_i \leq (1 - \delta) b_i + \delta u_i^T$,
 - if $\mu_i^T = 1$, then $x_i \geq (1 - \delta) b_i + \delta u_i^T$, and
 - if $\mu_i^T \in (0, 1)$, then $x_i = (1 - \delta) b_i + \delta u_i^T$.

Then the set of Period 1 proposals identified in step (3) have the property that, following any proposal in that set, there exists a continuation equilibrium involving the Period 1 acceptance probability vector μ (as well as continuation values that support the equilibrium).

Despite its conceptual simplicity, the application of this algorithm to all $\mu \in \mathcal{M}$ involves quite a bit of rather tedious - essentially mechanical - work. We relegate these details to the Appendix and present only one example in the main text, followed by a geometric illustration of the final result.

Example

Fix $\mu = (1, 0, 1, 0)$. (Both responders vote Y if and only if they are low types.)

1. Beliefs following proposal failure (both vote N) are given by $\omega = (1, 1)$. (The Proposer is sure that both are high types.)
2. The Period 2 proposal can be any mix of $(h, 0)$ and $(0, h)$ (see Figure 1.1). Therefore, the set of possible continuation value vectors $u = (u_1^L, u_1^H, u_2^L, u_2^H)$ is

$$\mathcal{U}(\mu) = \{(qh, qh, (1-q)h, (1-q)h) : q \in [0, 1]\}$$

where q denotes the probability assigned to the Period 2 proposal $(h, 0)$.

3. Given $(\mu_i^L, \mu_i^H) = (1, 0)$, the proposal (x_1, x_2) must be such that there exists $q \in [0, 1]$ such that

$$\begin{aligned} (1-\delta)l + \delta qh &\leq x_1 \leq (1-\delta)h + \delta qh \\ (1-\delta)l + \delta(1-q)h &\leq x_2 \leq (1-\delta)h + \delta(1-q)h. \end{aligned}$$

Step (3) yields a condition identifying the set of Period 1 proposals (x_1, x_2) such that there exists a continuation equilibrium involving the acceptance probability vector $\mu = (1, 0, 1, 0)$. Geometrically, that area $A(\mu)$ is the convex hull of six points, obtained by substituting $q = 0$ and $q = 1$ into the lower and upper bounds of the intervals identified in step (3):

$$A(1, 0, 1, 0) = \text{conv} \left\{ \begin{array}{ll} ((1-\delta)l, l + \delta\tau), & (l + \delta\tau, (1-\delta)l), \\ (h, (1-\delta)l), & ((1-\delta)l, h), \\ ((1-\delta)h, h), & (h, (1-\delta)h) \end{array} \right\}.$$

At different points within this area, the continuation equilibria involve P mixing between $(h, 0)$ and $(0, h)$ in specific ways in case Period 2 is reached. Details follow from the above inequalities. (In all cases, P 's expected Period 2 utility is $1 - h$.)

We can repeat this process for each $\mu \in \mathcal{M}$, identifying in each case a region in the $x_1 - x_2$ proposal space, such that for every proposal (x_1, x_2) in that region, there exists

a continuation equilibrium involving the acceptance probability vector μ . Details are presented in the Appendix. As that analysis shows, the areas associated with different μ *overlap*, meaning that many Period 1 proposals are consistent with multiple continuation equilibria.

Proposer-preferred continuation equilibria

Given the multiplicity of continuation equilibria following first round proposals, we suggest that it makes sense to select, for each possible proposal, the continuation equilibrium associated with the largest expected payoff for the Proposer. This can be justified by imagining that P announces which proposal she intends to make in Period 2 in case it is reached. If such an announcement is consistent with a continuation equilibrium, it is credible and the associated expectations are self fulfilling. The following Lemma implies that this is equivalent to selecting the continuation equilibrium associated with the largest probability of passage.

Lemma 4. Fix an arbitrary Period 1 proposal (x_1, x_2) . Suppose there exist two continuation equilibria with acceptance probability vectors $\hat{\mu} \neq \tilde{\mu}$, where $\hat{\mu}$ implies a higher probability of passage. Then P prefers the continuation equilibrium involving $\hat{\mu}$.

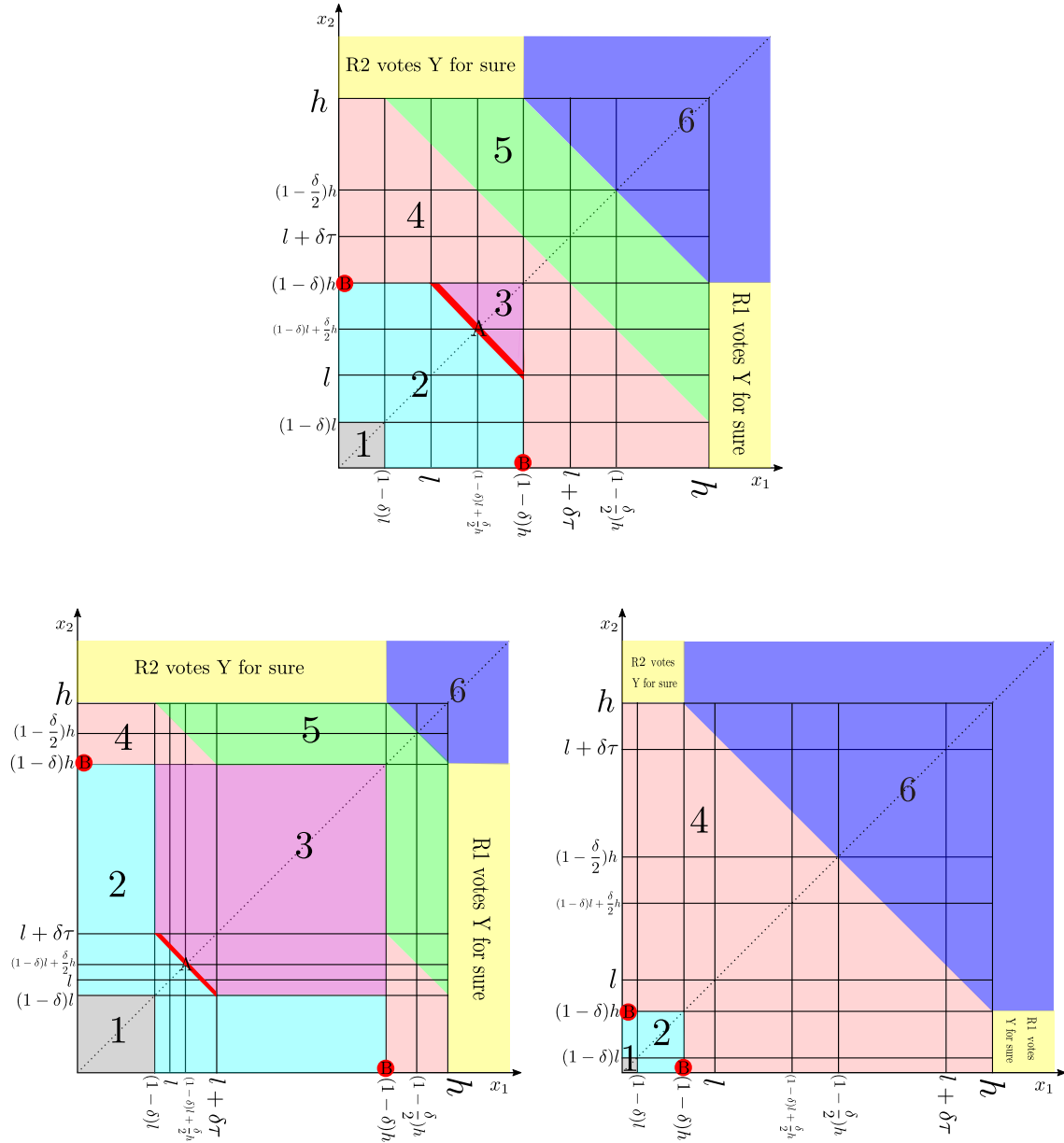
Proof. See Appendix 1.A.3. □

It turns out that this selection criterion eliminates all equilibria which involve mixing by either responder (see Appendix). Figure 1.2 presents the selected equilibria for the case that $\tau < \hat{\tau}^m$. Note that the shape of the areas depicted in this figure depend on the parameter values. For instance, see the lower two graphs of Figure 1.2 for variations in δ .

Proposition 1. *[Period 1 voting under majority rule] Following any Period 1 proposal (x_1, x_2) , the continuation equilibria involving the greatest probability of passage involve the following voting patterns (see Figure 1.2):*

1. *Region 1 (close to nothing to both responders): Both responders vote N for sure.*

Figure 1.2: Equilibria following Period 1 proposal (majority rule)



The figure depicts the equilibria with the largest probability of passage following any Period 1 proposal x_1 . The parameter values used are ($l = \frac{1}{10}$, $\tau = \frac{3}{10}$, and $\delta = \frac{1}{2}$) in the upper picture. In the lower pictures the situation with $\delta = \frac{1}{6}$ is depicted on the left and with $\delta = \frac{1}{2}$ on the right. See Proposition 1 for a description of each of the regions.

2. *Region 2 (small shares to both): One responder votes Y if he is a low type.*
3. *Region 3 (moderate and similar shares to both): Each responder votes Y if he is a low type.*
4. *Region 4 (generous share to one / small share to other): One responder votes Y for sure.*
5. *Region 5 (generous share to one / moderate share to other): One responder votes Y for sure, the other votes Y if he is a low type.*
6. *Region 6 (generous shares to both): Both responders vote Y for sure.*

Regions with asymmetric voting probabilities consist of three sub-regions: When one responder's share is (sufficiently) larger, he is the more likely to vote Y. When offers are (sufficiently) similar, two equilibria with the same probability of passage coexist.

1.4.4 Period 1 proposal

Having characterized (Proposer-preferred) continuation equilibria following all Period 1 proposals, we turn to the P's Period 1 choice of proposal. Note that both the probability that a proposal *passes* as well as P's continuation value in case of failure are constant within each of the regions depicted in Figure 1.2. It follows that only proposals that lie at the south west corner or boundary of a given region can be optimal. Also note that proposals in regions 4, 5, and 6 pass for sure, and consequently regions 5 and 6 are dominated by the cheapest proposals in Region 4, labeled (B) in the figures.

It follows that P's best choice is one of the following four: Offer nothing to both responders (or any other proposal that fails for sure), offer either responder $(1 - \delta)l$ and the other nothing (this passes with probability $\frac{1}{2}$), make any offer where $x_1 + x_2 = 2(1 - \delta)l + \delta h$ and both get more than l (passes with probability $\frac{3}{4}$, marked (A) in Figure 1.2), or offer

either responder $(1 - \delta)h$ and the other nothing (which passes for sure, marked (B)). Comparing these options reveals that either (A) or (B) are optimal. The following Proposition identifies the conditions under which either is optimal.

Proposition 2. *[Proposer-preferred equilibrium under majority rule] Consider majority rule and restrict attention to Proposer-preferred continuation equilibria following the first round proposal. Then,*

- **If** $\tau < \hat{\tau}^m$ **or** $\delta > \frac{4h-6l-1}{8h-6l-1}$: *In Period 1, P offers $(1 - \delta)h$ to one responder and zero to the other. The included player votes Y and so this proposal passes immediately. (If the included player were to vote N, P would offer h to the excluded responder in Period 2.)*
- **Otherwise:** *In Period 1, P proposes any (x_1, x_2) such that $x_1 + x_2 = 2(1 - \delta)l + \delta h$, $x_1 > (1 - \delta)l$, and $x_2 > (1 - \delta)l$. Both players vote Y iff they are low and so this proposal passes with probability 3/4. (If both responders vote N, P will offer one of them h in Period 2. The probability with which he includes R1 and R2 in this event varies depending on which responder is offered more in Period 1.)*

If δ is small, breakdown is likely and so responder prices depend on breakdown values. If in addition τ is large, the low type is significantly “cheaper” than the high type. Therefore, the “risky” option (A), where P makes a small offer to both responders, can be optimal. When δ is large, breakdown is unlikely, and so the fear of exclusion makes both types similarly cheap. If τ is small, the prices are similar anyway. Thus, in both cases, P is better off offering one responder enough to secure his vote for sure.

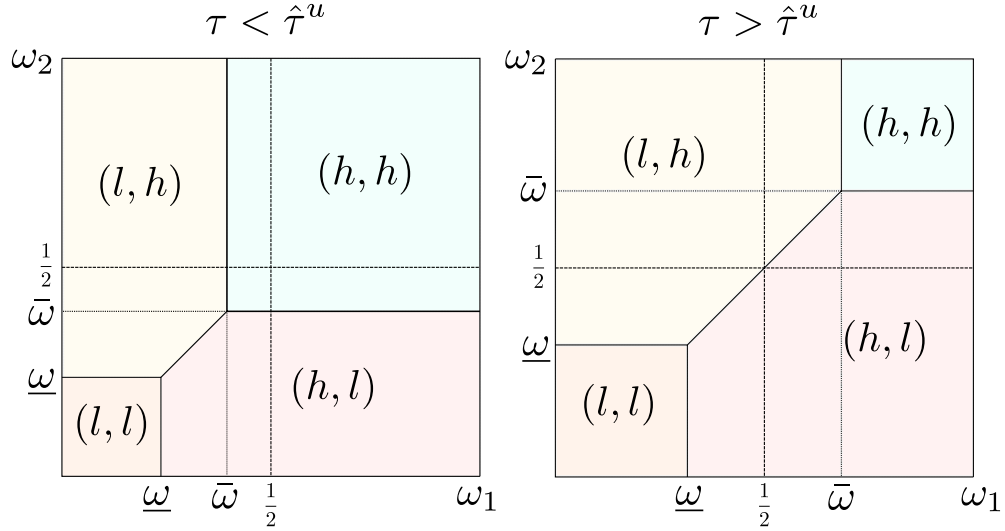
1.5 Unanimity rule

We now turn to an analysis of unanimity rule, following a similar outline based on backward induction, beginning with the Period 2 voting stage.

1.5.1 Period 2 voting and proposals

Lemma 1 applies to unanimity rule as well. Given this, the optimal Period 2 proposal is again determined by beliefs $\omega = (\omega_1, \omega_2)$. The functional form is presented in Appendix 1.B.1. Figure 1.3 displays the result.

Figure 1.3: Period 2 proposals (unanimity rule)



The figure depicts the Period 2 proposals that P prefers to make under unanimity rule given arbitrary beliefs about the responders' types. The horizontal and vertical axes measure the probability that R1 and R2 are of the high type, denoted ω_1 and ω_2 respectively. The left and right panels distinguish the cases where τ is smaller or greater than $\hat{\tau}^u$, which determines the optimal proposal in case $\omega_1 = \omega_2 = \frac{1}{2}$. We define $\bar{\omega} \equiv \frac{h-l}{1-h-l}$ and $\underline{\omega} \equiv \frac{h-l}{1-2l}$.

As under unanimity rule, the qualitative pattern of proposals depends on whether the difference between the low and high breakdown values exceeds a particular threshold, which we define as

$$\hat{\tau}^u \equiv \frac{1-2l}{3}.$$

The horizontal and vertical boundaries of the areas in these figures are defined by two levels of beliefs, which we denote $\bar{\omega} \equiv \frac{h-l}{1-h-l}$ and $\underline{\omega} \equiv \frac{h-l}{1-2l}$. The latter is always strictly smaller than $\frac{1}{2}$ (due to our assumption $2h < 1$). The former can be greater or less than $\frac{1}{2}$, thereby determining the optimal proposal at $\omega = (\frac{1}{2}, \frac{1}{2})$, i.e., in case no information is

revealed in Period 1. Specifically, $\bar{\omega} < \frac{1}{2}$ iff $\tau < \hat{\tau}^u$. Therefore, if $\tau < \hat{\tau}^u$, then P would offer (h, h) if Period 2 were reached without information being revealed, otherwise she would be indifferent between offering (h, l) or (l, h) .

1.5.2 Continuation values and beliefs

As in the case of majority rule, the optimal Period 2 proposal and expected payoffs depend on beliefs ω induced by the prior history.⁷ The following Lemma summarizes useful facts about these continuation values.

Lemma 5. In any equilibrium under unanimity rule:

- At any history s , Responder i 's Period 2 expected payoff satisfies

$$l \leq u_i^L(s) \leq u_i^H(s) = h.$$

- Let $\hat{s}$ and $\tilde{s}$ be two histories which induce beliefs $(\hat{\omega}_i, \hat{\omega}_{-i})$ and $(\tilde{\omega}_i, \tilde{\omega}_{-i})$, respectively. If $\hat{\omega}_i \geq \tilde{\omega}_i$ and $\hat{\omega}_{-i} = \tilde{\omega}_{-i}$, then $u_i^L(\hat{s}) \geq u_i^L(\tilde{s})$. That is, low types prefer to be perceived as high types.

Proof. The first part follows from the fact that P will never offer either responder more than h , and both responders must vote Y for the proposal to pass. To see the second part, look at Figure 1.3, let $i = 1$, and hold ω_2 constant. If $\omega_2 < \underline{\omega}$ or $\omega_2 > \bar{\omega}$, increasing ω_1 only affects the Period 2 offer made to R1, possibly increasing it from l to h , clearly increasing his expected payoff. If $\omega_2 \in (\underline{\omega}, \bar{\omega})$, increasing ω_1 may cause the Proposer to shift from offering (l, h) to offering (h, l) . Again, this can only increase R1's payoff, as he *may* end up with h and can never do worse than getting l . $\square$

⁷As above, some beliefs ω allow for P to mix between several proposals in Period 2, and so these ω are consistent with an entire *set* of proposals and expected payoffs. We will take this into account in the following analysis.

In contrast to majority rule, the set of circumstances under which Period 2 is reached is larger. In particular, it will be reached whenever at least one player has voted N. Therefore, in addition to (on path) beliefs about responders who voted N,

$$\omega_i^N = \frac{1 - \mu_i^H}{2 - \mu_i^H - \mu_i^L},$$

we must consider beliefs about players who voted Y, denoted

$$\omega_i^Y = \frac{\mu_i^H}{\mu_i^H + \mu_i^L}.$$

Recall that off-path beliefs are fixed by assumption to $\omega_i^N = 1$ if $\mu_i = (1, 1)$ and $\omega_i^Y = 0$ if $\mu_i = (0, 0)$.

1.5.3 Period 1 voting

Fix an arbitrary Period 1 proposal (x_1, x_2) . An immediate consequence of Lemma 5 is that a high type responder votes Y if and only if he is offered at least h .⁸ This is in contrast to majority rule, where a high type responder is willing to accept $(1 - \delta)h$ because he expects to be excluded if Period 2 is reached. Given this, low types must also vote Y if offered h or more.⁹

Lemma 6. Let (x_1, x_2) be an arbitrary Period 1 proposal. Then in any equilibrium under unanimity rule,

1. if $x_i \geq h$, then $\mu_1^L = \mu_1^H = 1$, and
2. if $x_i < h$, then $\mu_i^H = 0$.

⁸Voting Y (N) on less (more) attractive proposals is weakly dominated. Voting Y when offered exactly h is without loss of generality.

⁹Suppose R1 votes N with positive probability on such a proposal (only) when his type is low. This is *strictly* worse than voting Y if R2 votes Y . (Instead of $x_1^1 \geq h$, R1 gets at most $(1 - \delta)l + \delta h$). Suppose R2 votes N . Then the proposal fails irrespective of R1's vote. Given that he votes N only when he is a low type, beliefs will be $\omega_1^N = 0$. By voting Y instead, he would induce the belief $\omega_1^Y > \frac{1}{2}$, yielding a (weakly) greater continuation payoff. Thus, voting N is weakly dominated, a contradiction.

Proof. See discussion above. $\square$

It follows that a proposal that allocates at least h to both responders will pass immediately. Therefore, what remains to be analyzed is the probability with which low type responders vote Y on proposals that allocate strictly less than h to at least one responder. Within this set, it is helpful to consider separately proposals that allocate (at least) h to one responder and less than h to the other, before considering those which allocate strictly less than h to both.

Without loss of generality, consider a Period 1 proposal of the form (x_1, h) with $x_1 < h$. Then R2 votes Y for sure, making R1 pivotal. It is then straightforward to verify the following.

Lemma 7. [Unanimity rule] Let (x_1, x_2) be a Period 1 proposal with $x_2 \geq h$ and $x_1 < h$. Then, in any equilibrium, R2 votes Y irrespective of his type and R1 votes Y only if he is a low type and

$$x_1 \geq \begin{cases} l + \delta\tau & \text{if } \tau < \hat{\tau}^u \\ l + \frac{\delta}{2}\tau & \text{if } \tau > \hat{\tau}^u \end{cases}.$$

Proof. See discussion above. $\square$

Continuation equilibria when $x_{i1} < h$ for $i = 1, 2$

Next, we turn to proposals that allocate *strictly less than h to both responders*. Then both responders vote N if they are high types, and what remains to be determined are the probabilities with which they accept when low. Denote these by $\mu^L = (\mu_1^L, \mu_2^L)$.

Mirroring our majority rule analysis, we now describe an *algorithm* that can be used to fully characterize the set of continuation equilibria following all first round proposals that allocate *strictly less than h to both responders*. Recall that, in contrast to majority rule, Period 2 can now be reached even in case one responder has voted Y in Period 1. Hence we denote Period 2 continuation values of a low type responder by $u_i^{V_i V_{-i}} =$

$u_{i2}^L((x_1, x_2), (V_1, V_2))$. For example, u_2^{NY} denotes the continuation value of the low type of R2 given Period 2 has been reached after a N-vote of R2 and a Y-vote of R1.

Algorithm to characterize continuation equilibria following Period 1 proposals allocating less than h to both responders (unanimity rule)

Let $\mathcal{M} = [0, 1]^2$ be the set of low type *acceptance probability vectors* $\mu^L = (\mu_1^L, \mu_2^L)$. (Recall high types vote N on all proposals being considered.) For each $\mu^L \in \mathcal{M}$,

1. Identify the *belief vectors* $\omega^{NN} = (\omega_1^N, \omega_2^N)$, $\omega^{YN} = (\omega_1^Y, \omega_2^N)$ and $\omega^{NY} = (\omega_1^N, \omega_2^Y)$, induced by a history in which at least one responder has voted N , where in each case $\omega_i^N = \frac{1}{2-\mu_i^L}$ and $\omega_i^Y = 0$.
2. Characterize the (set of) *continuation value vectors* for low types $u_2^L = (u_1^{NN}, u_2^{NN}, u_1^{YN}, u_2^{NY}, u_1^{NY}, u_2^{YN})$, where for example (u_1^{YN}, u_2^{NY}) is consistent with Period 2 equilibrium play given beliefs ω^{YN} (after R1 voted Y and R2 voted N). If any of the belief vectors ω^{NN} , ω^{YN} , or ω^{NY} allows for multiple Period 2 equilibria, there will exist a *set* of consistent continuation value vectors, which we denote by $\mathcal{U}(\mu)$.
3. Identify the (set of) *Period 1 proposals* (x_1, x_2) with the property that there is *some* continuation value vector $u_2^L \in \mathcal{U}(\mu)$ such that:

- if $\mu_i^L = 0$,

$$\frac{\mu_{-i}^L}{2}x_i + \left(1 - \frac{\mu_{-i}^L}{2}\right) [(1-\delta)l + \delta u_i^{YN}] \leq (1-\delta)l + \delta \left[\frac{\mu_{-i}^L}{2}u_i^{NY} + \left(1 - \frac{\mu_{-i}^L}{2}\right)u_i^{NN} \right],$$

where $\frac{\mu_{-i}^L}{2}$ is the probability with which the “other” responder votes Y .

- if $\mu_i^L = 1$, the inequality is reversed, and
- if $\mu_i^L \in (0, 1)$, it holds with equality.

This condition can be conveniently restated as saying that i votes Y as a low type if $\mu_{-i}^L \neq 0$ and

$$x_i \geq (1-\delta)l + \delta \left[u_i^{NY} + \frac{2-\mu_{-i}^L}{\mu_{-i}^L} (u_i^{NN} - u_i^{YN}) \right]$$

with mixing permitted in case of equality.

We illustrate the application of the algorithm using an example. All other cases are analyzed in the Appendix.

Example

Fix $\mu^L = (1, 1)$. (Both responders vote Y if and only if they are low types.)

Any responder voting N reveals that he is a high type. Thus,

1. Period 2 beliefs are given by $\omega^{NN} = (1, 1)$, $\omega^{YN} = (0, 1)$ and $\omega^{NY} = (1, 0)$.
2. The continuation value vector is uniquely determined as

$$(u_1^{NN}, u_2^{NN}, u_1^{YN}, u_2^{YN}, u_1^{NY}, u_2^{NY}) = (h, h, l, h, h, l).$$

3. Given $\mu_i^L = 1$, the relevant set of Period 1 proposals consists of those satisfying

$$x_i \geq l + 2\delta(h - l) \text{ for } i = 1, 2$$

which satisfies $x_i < h$ only if $\delta < \frac{1}{2}$.

Step (3) gives a condition identifying the set of Period 1 proposals x such that there exists a continuation equilibrium involving the acceptance probability vector $\mu = (1, 0, 1, 0)$. Geometrically, this set is the following convex hull

$$A(1, 0, 1, 0) = \text{conv} \{(h, h), (l + 2\delta\tau, l + 2\delta\tau), (l + 2\delta\tau, h), (h, l + 2\delta\tau)\}.$$

We can repeat this process for each $\mu^L \in \mathcal{M}$, resulting in a full characterization of all continuation equilibria following any Period 1 proposal. Each $\mu^L \in \mathcal{M}$ is associated with a region in proposal space such that for each Period 1 proposal in that region, a continuation equilibrium involving the acceptance probability vector $\mu = (\mu_1^L, 0, \mu_2^L, 0)$ exists. The details of this analysis are presented in the Appendix.

Continuation equilibria with the largest probability of passage

As in the case of majority rule, the regions associated with different continuation equilibria overlap, reflecting the multiplicity of equilibria that results from the endogenous signaling

effects associated with each voting pattern. We again resolve this multiplicity by selecting the equilibrium associated with the largest probability of passage.¹⁰ The results are summarized in Proposition 3. Figure 1.4 provides a diagrammatic illustration for the case that $\tau > \hat{\tau}^u$ and $\delta < \frac{\bar{\mu}}{2}$.

Proposition 3. *[Period 1 voting under unanimity rule] Assume unanimity rule. Following any Period 1 proposal (x_1, x_2) , the continuation equilibria involving the greatest probability of passage involve the following voting patterns (see Figure 1.4):*

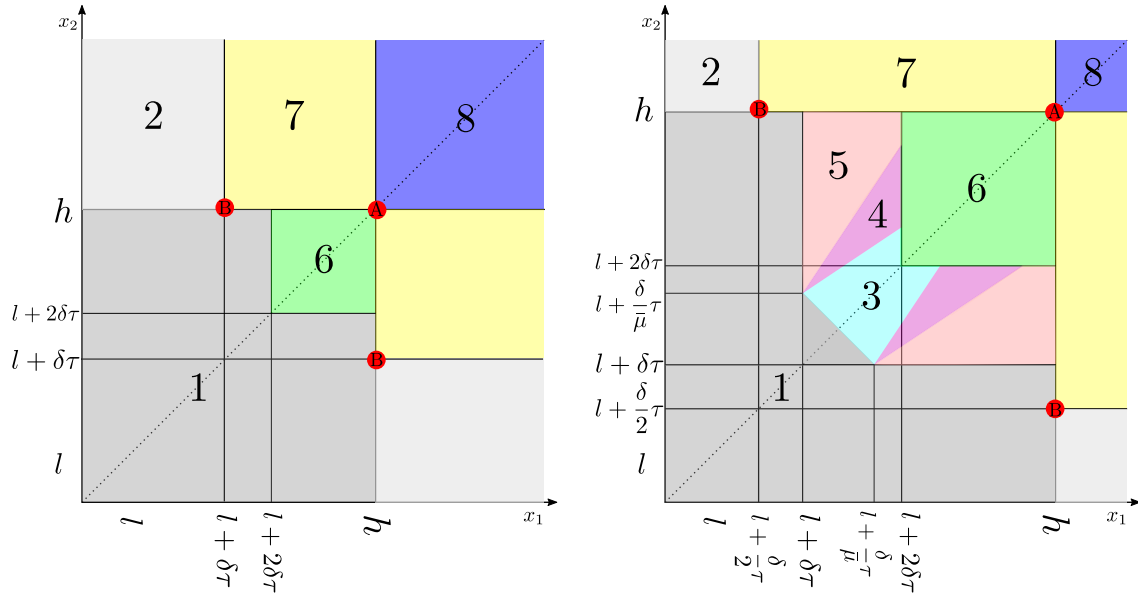
1. *Region 1 (allocating a small share to at least one responder): Both responders vote N irrespective of their type.*
2. *Region 2 (allocating a small share to one responder and at least h to the other): The responder offered less votes N , the other votes Y , both irrespective of their type.*
3. *Region 3 (close to symmetric, allocating moderate shares to both): Each responder votes Y with probability $\bar{\mu} = \frac{3h-l-1}{h-l}$ if he is a low type.*
4. *Region 4 (less symmetric, allocating a moderate share to one and a more generous share to the other): The responder offered less votes Y with probability $\bar{\mu}$ if he is a low type. The other votes Y with a larger probability if he is a low type.*
5. *Region 5 (even less symmetric proposals, allocating a moderate share to one and a generous share to the other): The responder offered less votes Y with probability $\bar{\mu}$ if he is a low type. The other votes Y for sure if he is a low type.*
6. *Region 6 (allocating more than $l + 2\delta\tau$ to each responder): Each responder votes Y if he is a low type.*

¹⁰As in the case of majority rule, this assumption can be motivated by imagining that P could make a self-fulfilling announcement as to her intentions. The argument is complicated slightly by the fact that, under unanimity rule, P may prefer equilibria associated with a lower probability of passage following certain Period 1 proposals. However, it can be shown that such proposals are dominated by others, so that our selection criterion is without consequence for equilibrium play. See Section 1.B.3 in Appendix for a more detailed discussion.

7. *Region 7 (allocating a moderate share to one responder and at least h to the other): The responder offered less votes Y if he is a low type, the other votes Y irrespective of his type.*
8. *Region 8 (allocating at least h to both responders): Both responders vote Y irrespective of their type.*

These equilibrium areas are ordered in ascending order of the probability of passage.

Figure 1.4: Equilibria following Period 1 proposal (unanimity rule)



The figure depicts the equilibria with the largest probability of passage following any Period 1 proposal x_1 . The parameter values used are ($l = \frac{1}{10}$, $\tau = \frac{2}{10}$, $\delta = \frac{1}{4}$ so that $\tau < \hat{\tau}^u$) in the picture on the left and ($l = \frac{1}{10}$, $\tau = \frac{1}{3}$, $\delta = \frac{1}{4}$ so that $\tau > \hat{\tau}^u$ and $\bar{\mu} = \frac{3}{5}$) in the one on the right.

1.5.4 Period 1 proposal

Having characterized the continuation equilibria with the largest probability of passage following all Period 1 proposals, we turn to P's Period 1 choice of proposal. The probability

that a proposal *passes* is constant within all the areas depicted in Figure 1.4, with Region 4 being an exception.¹¹ For these areas, it follows that only proposals that lie at the southwest boundary or corner of a given area can be optimal. It can be shown that the best offer in Region 5 dominates all offers in Region 3 and Region 4, respectively.

Thus P's optimal Period 1 proposal must be one of the following: A proposal that fails for sure (Region 1 or 2); a proposal such that one responder votes Y with probability $\bar{\mu}$ as a low type while the other votes Y for sure as a low type (Region 5); a proposal which both responders support if and only if they are low (Region 6); buying both responders for sure (point **(A)**); or point **(B)** where one responder is paid enough to secure his vote while the other is offered a smaller share such that he votes Y if and only if he is low. If $\tau < \hat{\tau}^u$, it can be shown that option **(A)** dominates all other options. If $\tau > \hat{\tau}^u$, it can be shown that proposal **(B)** dominates all other proposals.

Proposition 4. *[Proposer-preferred equilibrium under unanimity rule] Consider unanimity rule and restrict attention to the continuation equilibria with the largest probability of passage following the first round proposal (see Figure 1.4). Then,*

- **If $\tau < \hat{\tau}^u$:** In Period 1, P proposes (h, h) and both responders vote Y . (If either responder votes N , P proposes (h, h) again in Period 2.)
- **If $\tau > \hat{\tau}^u$:** In Period 1, P offers h to one responder, who votes Y for sure, and $l + \frac{\delta}{2}\tau$ to the other, who votes Y iff he is low. (If the responder that was offered the smaller share votes N , he is offered h in Period 2, while the other responder is offered l .)

The intuition underlying this result is as follows. If the difference between high and low breakdown values, τ , is small, P prefers to pay both responders h to secure immediate agreement. For larger τ , P prefers to take a risk by trying to buy one responder “cheap”, securing agreement with probability $\frac{1}{2}$. Even so, P offers the other responder h in order

¹¹Region 4 involves both responders mixing between voting Y and N . One responder votes Y with fixed probability $\bar{\mu}$, the other's probability varies between $(\bar{\mu}, 1)$.

to secure his vote for sure. Doing so not only increases the probability of passage from $\frac{1}{4}$ to $\frac{1}{2}$, it also makes the disadvantaged responder cheaper because the price for his vote decreases from $\max\{l + 2\delta\tau, h\}$ to $l + \frac{\delta}{2}\tau$ if he expects his counterpart to vote Y for sure rather than only when he is a low type. The reason is that the disadvantaged responder becomes pivotal, eliminating the negative signaling value of voting Y (as this results in immediate agreement).¹²

1.6 Unanimity vs. majority rule

We now turn to a comparison of unanimity and majority rule. Our goal is to make formally precise the notion that responders are “more expensive” and that immediate agreement is “less likely” or “more difficult to achieve” under unanimity rule. Such a comparison is complicated by the fact that the “price” of a responder’s vote depends on several factors, including his expectations concerning the other responder’s voting behavior. Another complication is that some offers can induce responders to mix between voting Y and N . In what follows, we use the term “price” to refer to the amount that a responder must be offered in order to secure his vote, i.e., in order for him to vote Y with probability 1.

1.6.1 Period 1 “prices”

Propositions 1 and 3 identify conditions on x_{i1} such that a low or high type responder i would vote Y on a proposal in equilibrium, taking the other responder’s voting probabilities as given. For simplicity, we restrict attention to cases where μ_{-i} reflects a pure strategy, i.e., $\mu_{-i} = (\mu_{-i}^L, \mu_{-i}^H) \in \{(0, 0), (1, 0), (1, 1)\}$. We define the corresponding “prices” as follows.

¹²To understand why the threshold determining the equilibrium is exactly $\hat{\tau}^u$, consider a Period 1 offer such that R2 votes Y for sure. Then, R1 anticipates that voting N (inducing a belief $(\omega_1^N, \frac{1}{2})$ with $\omega_1^N > \frac{1}{2}$) leads to second period proposal (h, h) or (h, l) depending on whether $\tau \leq \hat{\tau}^u$, causing a discrete change in his “price” at that point. One might expect that P would be more willing to “take a risk” in Period 1 if δ is larger. But the same is true for the responder, who will perceive a greater signaling value from voting N and so his price goes up. It turns out that these factors cancel so as to make δ irrelevant.

Definition 2. Let $\mu_{-i} \in \{(0, 0), (1, 0), (1, 1)\}$ be fixed. Then the Period 1 price of a type T responder under voting rule $v \in \{m, u\}$ is denoted $z_T^v(\mu_{-i})$, and defined as the smallest value of x_{i1} such that $\mu_i^T = 1$ is consistent with the relevant Proposition 1 or 3.

Under majority rule, each type's price is actually independent of μ_{-i} , and given by $(1 - \delta)b_i$. That is, $z_H^m(\mu_{-i}) = (1 - \delta)h$ and $z_L^m(\mu_{-i}) = (1 - \delta)l$. These prices reflect the fact that P can credibly announce that she plans to exclude the responder to whom she is making a Period 1 offer if that responder votes N. When $\delta \rightarrow 1$, this threat of exclusion looms large and the price of a vote tends to zero. As $\delta \rightarrow 0$, the responder's breakdown value effectively becomes an outside option and so the price approaches b_i .

Under unanimity rule, the high type responder's price is also independent of μ_{-i} and given by $z_H^u(\mu_{-i}) = h$ (see Lemma 6). Thus, high types are unambiguously more expensive under unanimity rule than under majority rule. This reflects the fact that both responders have veto power, so there is no reason to accept anything less than h .

In contrast, a *low type* responder's price under unanimity rule does depend on μ_{-i} . In particular,

$$z_L^u(1, 1) = \begin{cases} l + \frac{\delta}{2}\tau & \tau > \hat{\tau}^u \\ l + \delta\tau & \tau < \hat{\tau}^u, \end{cases}$$

$$z_L^u(1, 0) = \min\{l + 2\delta\tau, h\},$$

and

$$z_L^u(0, 0) = h.$$

Note that each of these prices exceeds l and so the low type is also unambiguously more expensive under unanimity rule than under majority rule. This reflects two circumstances. First, veto power implies that a payoff of at least l can be guaranteed by simply voting N consistently. Second, the low type can hope to achieve an even greater payoff if P can be made to believe that he is a high type. Thus, the low type must be compensated for

revealing his type. This *signaling incentive* is more relevant the lower is the probability with which the other responder votes Y. When $\mu_{-i} = (1, 1)$, Responder i expects to be pivotal and is “cheaper” than when $\mu_{-i} = (1, 0)$, in which case he expects that Period 2 might be reached even if he votes Y, in which case he would be “punished” for revealing his type. When $\mu_{-i} = (0, 0)$, this signaling incentive is all that is relevant, and so the low type must pool with the high type, inducing a “price” of h .¹³

Figure 1.5 presents responder prices as functions of δ for a given combination of parameter values ($l = \frac{1}{10}$ and $\tau = \frac{3}{10}$). As we have noted, majority rule prices (*dashed lines*) are decreasing in δ , as the threat of exclusion looms large when breakdown is unlikely. In contrast, unanimity rule prices (*solid lines*) *increase* in δ . This reflects the fact that the *positive signaling value* of voting N is more important the more likely it is that P will be able to make a second proposal.

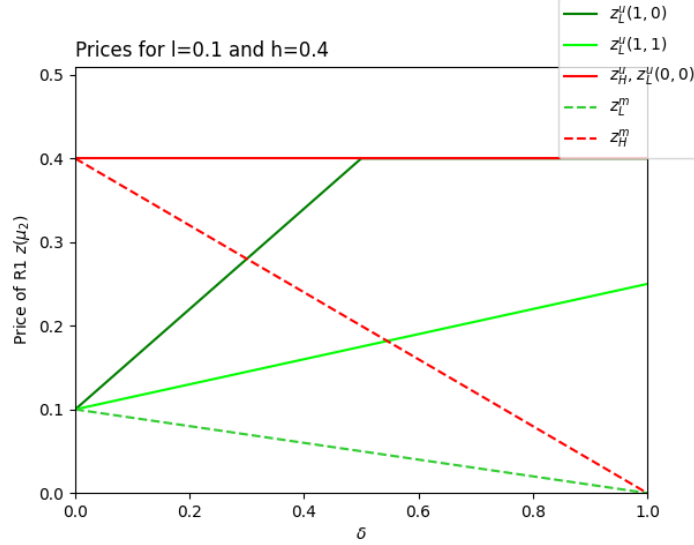
1.6.2 Probability of breakdown

In order to assess the efficiency of the two rules, we compare the probability of delay and breakdown. Under unanimity rule, delay can occur if and only if the two responder types are sufficiently different ($\tau > \hat{\tau}^u$). Then, P offers h to one and to the other something that they accept only if they are low. If the latter rejects, P offers him h in Period 2, and l to the first. In both cases, the disadvantaged responder accepts with probability $\frac{1}{2}$. Therefore, delay occurs with probability $\frac{1}{2}$ in both periods, and the probability of inefficient breakdown is $\frac{1}{2} (1 - \delta + \frac{\delta}{2}) = \frac{1}{2} - \frac{\delta}{4}$. If, on the other hand, the types are similar ($\tau < \hat{\tau}^u$), P prefers to offer both responders h in Period 1 and agreement is certain.

Under majority rule, delay can occur if and only if $\tau > \hat{\tau}^m$ and $\delta < \frac{4h-6l-1}{8h-6l-1}$. That is, types are sufficiently different and the probability of breakdown is sufficiently large.

¹³Under unanimity rule, there are also cutoff values above which low type responders mix between voting Y and N . These cutoff values are $\begin{cases} l + \frac{\delta}{2}\tau & \mu_{-i} = (1, 1) \\ l + \delta\tau & \mu_{-i} = (1, 0) \wedge \tau > \hat{\tau}^u \\ l + 2\delta\tau & \mu_{-i} = (1, 0) \wedge \tau < \hat{\tau}^u \end{cases}$. Again, each of these “prices” is larger than l and so unambiguously larger than the low type’s price under majority rule.

Figure 1.5: Responders' prices



R1's prices as a function of the continuation probability δ under unanimity rule (solid lines) and majority rule (dashed lines) given R2's voting probabilities and given that $h = \frac{4}{10}$ and $l = \frac{1}{10}$ (i.e., $\tau > \hat{\tau}^u$). R2 is expected to play a pure strategy. For instance, $z_L^u(1, 0)$ is the price of the low type of R1 under unanimity rule given that R2 votes Y if and only if he is of a low type.

(Only) under these conditions, high types will be significantly more expensive than low types, so that P prefers to “gamble” by offering both responders something that only low types accept. Thus, delay occurs with probability $\frac{1}{4}$ (if both responders are high types). If the second period is reached, agreement is certain. Thus, the probability of *breakdown* is $\frac{1-\delta}{4}$. For $\tau < \hat{\tau}^m$ or $\delta > \frac{4h-6l-1}{8h-6l-1}$, agreement in Period 1 is certain under majority rule.

In sum, the probability of a breakdown is larger under unanimity rule under all conditions except when $\tau \in (\hat{\tau}^m, \hat{\tau}^u)$ (nonempty if $l < \frac{1}{14} \approx 0.07$) and δ is close enough to 0.¹⁴

¹⁴These conditions are extremely restrictive. For instance, if $l = 0.05$, then we must have $\tau \in (0.275, 0.3)$ and $\delta \leq 0.06$ (if $\tau \approx 0.3$). To get an intuition for this, consider the extreme case of $\delta = 0$ and $l = 0$. Under both rules, P compares two types of proposals: Those that pass for sure because she offers both responders enough to secure even the high type's vote, and those where she “gamble” by offering at least one responder something he might reject. If $\tau > \frac{1}{4}$, P prefers to take the gamble under majority rule and offer both responders the low type's price $l = 0$, which passes with probability $\frac{3}{4}$ (i.e., unless both are high types). Under unanimity rule, however, a similar gamble is too risky if $\tau < \frac{3}{4}$. P needs both responders to vote Y . Thus, even if she offers the low type's price to only one of the responders (and buys the other for sure), there is only a 50% chance that the proposal will pass. Therefore, P prefers to buy both high types under unanimity rule. Thus for these special parameter conditions, delay can only occur under majority

This result confirms the central part of the informal argument that motivates our analysis, namely that inefficiencies due to “tough” bargaining are more likely to occur under unanimity rule than under majority rule.

It is perhaps not surprising that agreement is more difficult to achieve under unanimity rule, given that P must convince both responders rather than just one. But our analysis reveals an additional, less obvious point: This is that part of the reason for possible inefficiencies is that unanimity rule causes responders to become more “expensive”, possibly inducing the Proposer to take a risk by making a proposal that could fail. Under majority rule, in contrast, even high type responders will be “cheap” to buy (except under special circumstances) such that P can afford to make a proposal that will pass for sure.

The generally lower probability of (inefficient) breakdown under majority rule, in combination with the mostly lower prices for responders, lead to the Proposer being better off under majority rule than under unanimity rule. Responders in contrast prefer, in most cases, unanimity rule. While responders can be sure to end up with at least their breakdown value under unanimity rule, they must fear exclusion under majority rule. Hence, high types certainly prefer unanimity voting. Low types, in contrast, prefer majority rule if $\tau \in (\hat{\tau}^u, \hat{\tau}^m)$ and $\delta < \frac{3h-l}{h-3l}$ (which is non-empty if $l \in (\frac{1}{14}, \frac{1}{6})$). Here, the responder, under unanimity rule, fears breakdown whereas under majority rule agreement is certain (due to $\tau \in (\hat{\tau}^u, \hat{\tau}^m)$). In addition, the fear of Period 2 exclusion under majority rule is low (due to the low δ) so that P ends up making a large Period 1 offer.

1.7 Discussion

The choice between alternative q-majority rules, including unanimity rule, is a central problem in constitutional design. Unanimity rule has the attractive property that decisions taken are guaranteed to be *efficient* in the sense that all members prefer the proposed change relative to the status quo. A potential disadvantage is that agreement might be

rule.

more difficult to reach under unanimity rule *even if it is efficient*. This is because, even when all members of a group can potentially benefit, each individual member may have an incentive to overstate their opposition, in an attempt to secure a larger share of the surplus that results from agreement. Arguments along these lines have been made informally, among others by Buchanan and Tullock (1965). The goal of the present paper was to provide an explicit formalization of this argument in a multilateral bargaining game with private information.

Our central results confirm the informal argument that unanimity rule creates incentives to “act tough” and thereby makes agreement more difficult to achieve. In general, the prices necessary to secure a responder’s vote are higher under unanimity rule than under majority rule, *ceteris paribus*. The main reason for this is that voting N carries a positive “signaling value” under unanimity rule, while it is discouraged through the threat of subsequent exclusion under majority rule. The combination of higher prices and the need to secure more votes implies that the proposer will more often choose to risk delay and breakdown under unanimity rule, resulting in a larger probability of inefficient disagreement. In addition to confirming the informal argument outlined above, the formal analysis yields additional insights into the underlying incentives and the properties of optimal strategies.

For example, the analysis yields interesting comparative statics with respect to the continuation probability δ . Under unanimity rule, the high type’s price always corresponds to his breakdown value, since he can veto any other outcome. The low type’s price, however, is larger than his breakdown value and increases in δ . This is because acting “tough” is both less costly and more beneficial if the next period is reached with a larger probability following proposal failure. Under majority rule, in contrast, responders’ prices are generally lower than their breakdown values and decreasing in δ , and indeed approach zero as δ approaches 1. The intuition is that acting “tough” becomes counterproductive if Period 2 is likely to be reached, as the “tough” responder will simply be excluded from the Period 2 coalition.

Another insight concerns strategic complementarities in responders' voting choices. Under unanimity rule, a responder is more willing to vote Y (in the sense that his price is lower) the higher the probability that the *other* responder votes Y , in which case his own vote becomes pivotal. The reason is that voting Y carries a *negative signaling value* in case the proposal fails. The more likely it is that the other responder votes Y , the less relevant this becomes.¹⁵ This translates into an incentive for the proposer to offer one responder enough to secure his vote for sure, thereby making the other responder pivotal and consequently "cheap".¹⁶ Interestingly, the opposite is true under majority rule. Here, a responder is *less* willing to agree (his price is higher) the more likely the other responder is to vote Y .¹⁷

Finally, our analysis will be of interest to researchers working on formal approaches to bargaining and voting with private information. We were surprised by the the rich complexity that we encountered in analyzing a model that might appear quite simple at first sight. (Three players, a fixed proposer, only two types, and two rounds of negotiation.) It would be interesting to extend the analysis to more players, types, and longer / infinite time horizon. However, this is beyond the scope of our paper, and indeed our analysis might serve as caution that such a model may become intractable.

¹⁵There is one exception to this pattern: For a small interval of τ , R1's price is lower if R2 mixes with a certain probability μ_2^L when low than if R2 votes Y for sure when low. The reason is that if R2 votes Y if low, then in Period 2 after (N, N) P will offer the high share to both responders. This makes voting N more attractive compared to the case where P offers the high share only to R1 (and thus the Period 2 proposal only passes if R2 is low) - as in the case with $\mu_2^L < \bar{\mu}$. For this to hold we need $\mu_2^L \in (\frac{1}{2}, \bar{\mu})$ and thus $\tau > \frac{2-4t}{5}$ (so that $\bar{\mu} > \frac{1}{2}$).

¹⁶In a model involving a larger number of players, this may translate into an interesting trade-off: P will wish to offer a sufficiently large number of responders large enough shares to secure their certain agreement such that the remaining responders are sufficiently convinced that agreement is likely so as to make their votes pivotal, and therefore "cheap".

¹⁷The reasons underlying this effect are subtle and have to do with the beliefs formed in case the first round proposal fails. There, the precise way this plays out is specific to the three player case. The general insight is that under majority rule, responders are more likely to accept if they believe that they will be excluded from a future coalition. This threat of exclusion, in turn, will be more credible if *other* responders are not induced to signal their types, i.e., if P offers them something such that they vote either Y or N irrespective of their type. It appears potentially interesting to investigate in more detail the implications of this for the design of optimal proposals in larger groups.

Appendix

1.A Majority rule

1.A.1 Period 2 proposal (majority rule)

Consider any history preceding the Period 2 proposal stage, and let the corresponding beliefs be given by (ω_1, ω_2) . Suppose without loss of generality that $\omega_1 \leq \omega_2$. By Lemma 1, $x_2 = (h, 0)$ and $x_2 = (0, h)$ pass for sure, both yielding a Proposer payoff of $1 - h$. $x_2 = (l, l)$ passes with probability $(1 - \omega_1\omega_2)$, yielding $(1 - \omega_1\omega_2)(1 - 2l)$. $x_2 = (l, 0)$ dominates $x_2 = (0, l)$, and passes with probability $(1 - \omega_1)$, yielding $(1 - \omega_1)(1 - l)$. Comparing these options establishes that the optimal Period 2 proposal is given by

$$x_2(\omega_1, \omega_2) = \begin{cases} (h, 0) \text{ or } (0, h) & \text{if } \omega_1 > \frac{h-l}{1-l} \text{ and } \omega_1\omega_2 > \frac{h-2l}{1-2l}, \\ (l, 0) & \text{if } \omega_1 < \frac{h-l}{1-l} \text{ and } \frac{1-\omega_1}{1-\omega_1\omega_2} > \frac{1-2l}{1-l}, \\ (l, l) & \text{if } \omega_1\omega_2 < \frac{h-2l}{1-2l} \text{ and } \frac{1-\omega_1}{1-\omega_1\omega_2} < \frac{1-2l}{1-l}. \end{cases}$$

It is informative to consider the optimal proposal for $\omega = (\frac{1}{2}, \frac{1}{2})$, i.e., following any history in which no information has been revealed:

$$x_2\left(\frac{1}{2}, \frac{1}{2}\right) = \begin{cases} (h, 0) \text{ or } (0, h) & \text{if } \tau < \frac{1+2l}{4}, \\ (l, l) & \text{otherwise.} \end{cases}$$

1.A.2 Period 1 voting (majority rule)

We use the algorithm described in the main text to characterize the (set of) continuation equilibria following arbitrary Period 1 proposals that allocate less than h to both responders. The algorithm involves identifying, for each acceptance probability vector μ

consistent with Lemma 3, the set of Period 1 offers x_1 such that a continuation equilibrium involving the acceptance probabilities μ exists. The set of offers for which this is true will typically be characterized by a set of inequalities. In some cases, these inequalities will involve parameters reflecting alternative mixing probabilities for offers made in Period 2. The set of proposals x_1 which can satisfy the inequalities for some set of feasible parameters constitutes an area in Period 1 proposal space, which we will denote by $A(\mu)$. As we will see, $A(\mu)$ will typically be the convex hull of a set of points obtained by identifying the largest and smallest values that these parameters can take.

Acceptance vector $\mu = (0, 0, 0, 0)$ Then (1) beliefs following failure are $\omega = (\frac{1}{2}, \frac{1}{2})$. For step (2), we must make a case distinction:

(2a) If $\tau < \hat{\tau}^m$: The Period 2 proposal is any mix between $(h, 0)$ and $(0, h)$. Let ρ denote the probability that P proposes $(h, 0)$. Then the set of possible continuation values is $\mathcal{U}(\mu) = \{(\rho h, \rho h, (1 - \rho)h, (1 - \rho)h) : \rho \in [0, 1]\}$. Then (3a) to support μ , there must exist $\rho \in [0, 1]$ such that

$$\begin{aligned} x_1 &\leq (1 - \delta)l + \delta\rho h, \\ x_2 &\leq (1 - \delta)l + \delta(1 - \rho)h. \end{aligned}$$

The area for which such a ρ exists can be characterized by first considering the extreme cases $\rho = 0$ and $\rho = 1$. The first implies that $x_1 \in [0, (1 - \delta)l]$ and $x_2 \in [0, (1 - \delta)l + \delta h]$. These conditions describe the convex hull of the four points $(0, 0)$, $(0, (1 - \delta)l + \delta h)$, $((1 - \delta)l, 0)$, $((1 - \delta)l, (1 - \delta)l + \delta h)$. The second case ($\rho = 1$) is symmetric, requiring $x_1 \in [0, (1 - \delta)l + \delta h]$ and $x_2 \in [0, (1 - \delta)l]$, satisfied within the convex hull of the four points $(0, 0)$, $((1 - \delta)l + \delta h, 0)$, $(0, (1 - \delta)l)$, $((1 - \delta)l + \delta h, (1 - \delta)l)$. Next, we can imagine varying ρ between 0 and 1, tracing out the convex hull of all points identified thus far. Note that $(0, (1 - \delta)l)$ itself is in between $(0, 0)$ and $(0, (1 - \delta)l + \delta h)$, and similarly for $((1 - \delta)l, 0)$. And the point $(0, 0)$ appeared in

both cases. Thus of the eight points identified, three are redundant. The area we are looking for is thus the convex hull of five points:

$$A(0, 0, 0, 0) = \text{conv}\{(0, 0), (0, (1 - \delta)l + \delta h), ((1 - \delta)l, (1 - \delta)l + \delta h), ((1 - \delta)l + \delta h, (1 - \delta)l), ((1 - \delta)l + \delta h, 0)\}.$$

Similar reasoning can be applied to each of the cases we will consider in what follows, and we will not spell out all details each time.

(2b) If $\tau > \hat{\tau}^m$: The Period 2 proposal is (l, l) . Therefore the continuation values are uniquely determined as

$$u = \left(l, \frac{l + h}{2}, l, \frac{l + h}{2} \right).$$

(Low types will vote Y in Period 2, high types will vote N and expect the other to vote Y with prob $\frac{1}{2}$.) Then (3b), to support μ , the proposal must satisfy

$$x_i \leq l \text{ for } i = 1, 2$$

and so the corresponding area is

$$A(0, 0, 0, 0) = \text{conv}\{(0, 0), (0, l), (l, l), (l, 0)\}.$$

Acceptance vector $\mu = (1, 0, 0, 0)$ Then (1) beliefs following Period 1 proposal failure are $\omega = (1, \frac{1}{2})$. (2) The Period 2 proposal is any mix between $(h, 0)$ and $(0, h)$. Therefore, $\mathcal{U}(\mu) = \{(qh, qh, (1 - q)h, (1 - q)h) : q \in [0, 1]\}$. Then (3) to support μ , there must exist $q \in [0, 1]$ such that

$$\begin{aligned} (1 - \delta)l + \delta qh &\leq x_1 \leq (1 - \delta)h + \delta qh, \\ x_2 &\leq (1 - \delta)l + \delta(1 - q)h. \end{aligned}$$

The corresponding area is

$$A(1, 0, 0, 0) = \text{conv}\{((1 - \delta)l, 0), ((1 - \delta)l, (1 - \delta)l + \delta h), \\ ((1 - \delta)h, (1 - \delta)l + \delta h), (h, (1 - \delta)l), (h, 0)\}.$$

Acceptance vector $\mu = (1, 1, 0, 0)$ (1) Period 2 beliefs are $\omega = (1, \frac{1}{2})$. (2) Again $\mathcal{U}(\mu) = \{(qh, qh, (1 - q)h, (1 - q)h) : q \in [0, 1]\}$. (3) Given μ there exists $q \in [0, 1]$ such that

$$x_1 \geq (1 - \delta)h + \delta qh, \\ x_2 \leq (1 - \delta)l + \delta(1 - q)h.$$

The corresponding area is

$$A(1, 1, 0, 0) = \text{conv}\{((1 - \delta)h, 0), ((1 - \delta)h, (1 - \delta)l + \delta h), \\ (1 - (1 - \delta)l - \delta h, (1 - \delta)l + \delta h), (1, 0)\}.$$

Acceptance vector $\mu = (1, 0, 1, 1)$ (1) Beliefs following failure are $\omega = (1, 1)$ (R2's N-vote is “unexpected”). Again (2) $\mathcal{U}(\mu) = \{(qh, qh, (1 - q)h, (1 - q)h) : q \in [0, 1]\}$. (3) Given μ there exists $q \in [0, 1]$ such that

$$(1 - \delta)l + \delta qh \leq x_1 \leq (1 - \delta)h + \delta qh, \\ (1 - \delta q)h \leq x_2.$$

The corresponding area is

$$A(1, 0, 1, 1) = \text{conv}\{((1 - \delta)l, h), ((1 - \delta)l, 1 - (1 - \delta)l), \\ (h, 1 - h), (h, (1 - \delta)h), ((1 - \delta)l + \delta h, (1 - \delta)h)\}.$$

Acceptance vector $\mu = (1, 1, 1, 1)$ (1) Period 2 beliefs are $\omega = (1, 1)$. (2) Again $\mathcal{U}(\mu) = \{(qh, qh, (1 - q)h, (1 - q)h) : q \in [0, 1]\}$. (3) Given μ there exists $q \in [0, 1]$ such that

$$\begin{aligned} x_1 &\geq (1 - \delta)h + \delta qh, \\ x_2 &\geq (1 - \delta q)h. \end{aligned}$$

The corresponding area is

$$A(1, 1, 1, 1) = \text{conv}\{((1 - \delta)h, h), ((1 - \delta)h, 1 - (1 - \delta)h), \\ (1 - (1 - \delta)h, (1 - \delta)h), (h, (1 - \delta)h)\}.$$

Acceptance vector $\mu = (1, 0, 1, 0)$ This was covered as an example in the main text.

Acceptance vectors that involve one responder mixing These are: $\mu = (\mu_1^L, 0, 0, 0)$, $\mu = (\mu_1^L, 0, 1, 1)$, $\mu = (\mu_1^L, 0, 1, 0)$, $\mu = (1, \mu_1^H, 0, 0)$, $\mu = (1, \mu_1^H, 1, 1)$, and $\mu = (1, \mu_1^H, 1, 0)$.

Acceptance vector $\mu = (\mu_1^L, 0, 0, 0)$ **with** $\mu_1^L \in (0, 1)$ Then (1) Period 2 beliefs are $\omega = \left(\frac{1}{2 - \mu_1^L}, \frac{1}{2}\right)$. For step (2), we need to make a case distinction:

(2a) If $\tau < \hat{\tau}^M$ or $\left[\frac{1}{2} > \frac{h-l}{1-l} \text{ and } \omega_1/2 > \frac{h-2l}{1-2l}\right]$: The Period 2 proposal is any mix between $(h, 0)$ and $(0, h)$. Therefore $\mathcal{U}(\mu) = \{(qh, qh, (1 - q)h, (1 - q)h) : q \in [0, 1]\}$. Then

(3a) to support μ there must exist $q \in [0, 1]$ such that

$$\begin{aligned} x_1 &= (1 - \delta)l + \delta qh, \\ x_2 &< (1 - \delta)l + \delta(1 - q)h. \end{aligned}$$

The corresponding area is

$$\begin{aligned} A(\mu_1^L, 0, 0, 0) = \text{conv}\{((1 - \delta)l, 0), ((1 - \delta)l, (1 - \delta)l + \delta h), \\ ((1 - \delta)l + \delta h, (1 - \delta)l), ((1 - \delta)l + \delta h, 0)\}. \end{aligned}$$

Note that $A(\mu_1^L, 0, 0, 0) \subset A(1, 0, 0, 0)$.

(b) Otherwise, the Period 2 proposal is (l, l) and so continuation values are uniquely determined as

$$u = \left(l, \frac{l + h}{2}, l, \frac{l + h}{2} \right).$$

Therefore, given μ we have

$$\begin{aligned} x_1 &= l, \\ x_2 &< l. \end{aligned}$$

The corresponding area is the line segment

$$A(\mu_1^L, 0, 0, 0) = \text{conv}\{(l, 0), (l, l)\}.$$

Again, it can be shown that, given $\tau > \hat{\tau}^m$, $A(\mu_1^L, 0, 0, 0) \subset A(1, 0, 0, 0)$.

In both cases, $A(\mu_1^L, 0, 0, 0) \subset A(1, 0, 0, 0)$. Thus, each point x_1 that admits continuation equilibria involving $\mu = (\mu_1^L, 0, 0, 0)$ with $\mu_1^L \in (0, 1)$ also admits a continuation equilibrium involving $\mu = (1, 0, 0, 0)$.

Acceptance vector $\mu = (\mu_1^L, 0, 1, 1)$ (1) Period 2 beliefs are $\omega = \left(\frac{1}{2-\mu_1^L}, 1\right)$. (2) Again $\mathcal{U}(\mu) = \{(qh, qh, (1-q)h, (1-q)h) : q \in [0, 1]\}$. (3) Given μ there exists $q \in [0, 1]$ such that

$$\begin{aligned} x_1 &= (1-\delta)l + \delta qh, \\ x_2 &> (1-\delta q)h. \end{aligned}$$

The corresponding area is

$$\begin{aligned} A(\mu_1^L, 0, 1, 1) = \text{conv}\{ &((1-\delta)l, h), ((1-\delta)l, 1-(1-\delta)l), \\ &((1-\delta)l + \delta h, 1-(1-\delta)l - \delta h), ((1-\delta)l + \delta h, (1-\delta)h)\}. \end{aligned}$$

Acceptance vector $\mu = (\mu_1^L, 0, 1, 0)$ (1) Period 2 beliefs are $\omega = \left(\frac{1}{2-\mu_1^L}, 1\right)$. (2) Again $\mathcal{U}(\mu) = \{(qh, qh, (1-q)h, (1-q)h) : q \in [0, 1]\}$. (3) Given μ there exists $q \in [0, 1]$ such that

$$\begin{aligned} x_1 &= (1-\delta)l + \delta qh, \\ (1-\delta)l + \delta(1-q)h &\leq x_2 \leq (1-\delta q)h. \end{aligned}$$

The corresponding area

$$\begin{aligned} A(\mu_1^L, 0, 1, 0) = \text{conv}\{ &((1-\delta)l, (1-\delta)l + \delta h), ((1-\delta)l, h), \\ &((1-\delta)l + \delta h, (1-\delta)h), ((1-\delta)l + \delta h, (1-\delta)l)\}. \end{aligned}$$

Acceptance vector $\mu = (1, \mu_1^H, 0, 0)$ (1) Period 2 beliefs are $\omega = \left(1, \frac{1}{2}\right)$. (2) Again $\mathcal{U}(\mu) = \{(qh, qh, (1-q)h, (1-q)h) : q \in [0, 1]\}$. (3) Given μ there exists $q \in [0, 1]$ such

that

$$\begin{aligned} x_1 &= (1 - \delta)h + \delta qh, \\ x_2 &\leq (1 - \delta)l + \delta(1 - q)h. \end{aligned}$$

The corresponding area is

$$A(1, \mu_1^H, 0, 0) = \text{conv} \{ (0, (1 - \delta)l), (h, (1 - \delta)l), ((1 - \delta)h, (1 - \delta)l + \delta h), ((1 - \delta)h, 0) \}.$$

Acceptance vector $\mu = (1, \mu_1^H, 1, 1)$ (1) Period 2 beliefs are $\omega = (1, 1)$. (2) Again $\mathcal{U}(\mu) = \{(qh, qh, (1 - q)h, (1 - q)h) : q \in [0, 1]\}$. (3) Given μ there exists $q \in [0, 1]$ such that

$$\begin{aligned} x_1 &= (1 - \delta)h + \delta qh, \\ x_2 &\geq (1 - \delta q)h. \end{aligned}$$

The corresponding area is

$$A(1, \mu_1^H, 1, 1) = \text{conv} \{ ((1 - \delta)h, h), ((1 - \delta)h, 1 - (1 - \delta)h), (h, 1 - h), (h, (1 - \delta)h) \}.$$

Acceptance vector $\mu = (1, \mu_1^H, 1, 0)$ (1) Period 2 beliefs are $\omega = (1, 1)$. (2) Again $\mathcal{U}(\mu) = \{(qh, qh, (1 - q)h, (1 - q)h) : q \in [0, 1]\}$. (3) Given μ there exists $q \in [0, 1]$ such that

$$\begin{aligned} x_1 &= (1 - \delta)h + \delta qh, \\ (1 - \delta)l + \delta(1 - q)h &\leq x_2 \leq (1 - \delta q)h. \end{aligned}$$

The corresponding area is

$$A(1, \mu_1^H, 1, 0) = \text{conv} \{((1 - \delta)h, (1 - \delta)l + \delta h), ((1 - \delta)h, h), (h, (1 - \delta)h), (h, (1 - \delta)l)\}.$$

Voting profiles where both responders are mixing These cases are $\mu = (\mu_1^L, 0, \mu_2^L, 0)$, $\mu = (1, \mu_1^H, \mu_2^L, 0)$, and $\mu = (1, \mu_1^H, 1, \mu_2^H)$.

Acceptance vector $\mu = (\mu_1^L, 0, \mu_2^L, 0)$ (1) Period 2 beliefs are $\omega = \left(\frac{1}{2 - \mu_1^L}, \frac{1}{2 - \mu_2^L}\right)$. (2)

Case distinctions:

(2a) If $\tau < \hat{\tau}^M$ or $\left[\min\{\omega_1, \omega_2\} > \frac{h-l}{1-l} \text{ and } \omega_1\omega_2 > \frac{h-2l}{1-2l}\right]$:

Again $\mathcal{U}(\mu) = \{(qh, qh, (1-q)h, (1-q)h) : q \in [0, 1]\}$. Then (3a) given μ there exists $q \in [0, 1]$ such that

$$\begin{aligned} x_1 &= (1 - \delta)l + \delta qh, \\ x_2 &= (1 - \delta)l + \delta(1 - q)h. \end{aligned}$$

The corresponding area is

$$A(\mu_1^L, 0, \mu_2^L, 0) = \text{conv} \{((1 - \delta)l, (1 - \delta)l + \delta h), ((1 - \delta)l + \delta h, (1 - \delta)l)\}.$$

(2b) Otherwise, the Period 2 proposal is (l, l) and so the continuation values are uniquely determined as

$$u = \left(l, \frac{l+h}{2}, l, \frac{l+h}{2}\right).$$

Then (3b) to support μ , x_1 must satisfy

$$x_1 = x_2 = l.$$

The corresponding area is just a single point:

$$A(\mu_1^L, 0, \mu_2^L, 0) = (l, l).$$

Acceptance vector $\mu = (1, \mu_1^H, \mu_2^L, 0)$ (1) Period 2 beliefs are $\omega = \left(\frac{1}{2-\mu_2^L}, 1\right)$. (2) Again $\mathcal{U}(\mu) = \{(qh, qh, (1-q)h, (1-q)h) : q \in [0, 1]\}$, and (3) there exists $q \in [0, 1]$ such that

$$\begin{aligned} x_1 &= (1-\delta)h + \delta qh, \\ x_2 &= (1-\delta)l + \delta(1-q)h. \end{aligned}$$

The corresponding area is

$$A(1, \mu_1^H, \mu_2^L, 0) = \text{conv} \{((1-\delta)h, (1-\delta)l + \delta h), (h, (1-\delta)l)\}.$$

Acceptance vector $\mu = (1, \mu_1^H, 1, \mu_2^H)$ (1) Period 2 beliefs are $\omega = (1, 1)$. (2) Again $\mathcal{U}(\mu) = \{(qh, qh, (1-q)h, (1-q)h) : q \in [0, 1]\}$, and (3) there exists $q \in [0, 1]$ such that

$$\begin{aligned} x_1 &= (1-\delta)h + \delta qh, \\ x_2 &= (1-\delta)h + \delta(1-q)h. \end{aligned}$$

The corresponding area is

$$A(1, \mu_1^H, 1, \mu_2^H) = \text{conv} \{((1-\delta)h, h), (h, (1-\delta)h)\}.$$

1.A.3 Proof of Lemma 4

Let $u_P = 1 - x_1 - x_2$ denote P's utility from immediate passage of the proposal. Denote by $\tilde{p}$ and $\hat{p}$ the probabilities of passage associated with $\tilde{\mu}$ and $\hat{\mu}$, respectively. Similarly, let $\tilde{u}_F$ and $\hat{u}_F$ denote P's expected utilities following proposal failure in the corresponding

continuation equilibria. Note that $\tilde{p} < \hat{p} \leq 1$ and so the “tilde” equilibrium involves a positive probability of proposal failure. Assume (seeking a contradiction) that P prefers the “tilde” equilibrium. Then we have $\tilde{p}u_P + (1 - \tilde{p})\tilde{u}_F \geq \hat{p}u_P + (1 - \hat{p})\hat{u}_F$, or equivalently

$$(1 - \tilde{p})\tilde{u}_F - (1 - \hat{p})\hat{u}_F \geq (\hat{p} - \tilde{p})u_P > 0.$$

Suppose that $\hat{u}_F \geq \tilde{u}_F$. Then

$$(\hat{p} - \tilde{p})\tilde{u}_F = (1 - \tilde{p})\tilde{u}_F - (1 - \hat{p})\tilde{u}_F \geq (1 - \tilde{p})\tilde{u}_F - (1 - \hat{p})\hat{u}_F \geq (\hat{p} - \tilde{p})u_P,$$

thus $\tilde{u}_F \geq u_P$, i.e., P weakly prefers that her proposal fails in the “tilde” equilibrium. In that equilibrium, the Period 2 proposal is *either* **(a)** one of $(h, 0)$ and $(0, h)$ *or* **(b)** (l, l) *or* **(c)** a mixture between all three (see Figure 1.1 and recall that Period 2 beliefs following failure will always satisfy $\omega_i \geq \frac{1}{2}$).

In case (a) the Period 2 proposal allocates h to one responder and passes for sure, thus continuation values satisfy $u_1^H + u_2^H = h$. Since the equilibrium involves a positive probability of failure, both responders must vote N in Period 1 when high. Thus $x_i < (1 - \delta)h + \delta u_{iH}$ for $i = 1, 2$. Therefore, $x_1 + x_2 < 2(1 - \delta)h + \delta(u_1^H + u_2^H) = 2(1 - \delta)h + \delta h$. Then $u_P = 1 - x_1 - x_2 > 1 - 2(1 - \delta)h - \delta h$. Moreover $\tilde{u}_F = \delta(1 - h)$. Thus $\tilde{u}_F \geq u_P$ requires $\delta(1 - h) > 1 - 2(1 - \delta)h - \delta h$, which is equivalent to $2h > 1$, a contradiction.

Case (b) can occur only if $\tau > \hat{\tau}^m$ and $\tilde{\mu}_{il} < 1$ for $i = 1, 2$ (see Figure 1.1). Given that P offers (l, l) in Period 2, low type responders would vote Y for sure if $x_i > l$. Thus $x_1 + x_2 \leq 2l$. Hence $u_P = 1 - x_1 - x_2 \geq 1 - 2l > \delta(1 - 2l) > \tilde{u}_F$, where the last inequality follows from the fact that (l, l) passes with probability less than one in Period 2. Thus $u_P > \tilde{u}_F$, a contradiction.

Case (c) can only occur if P is indifferent between $(h, 0)$, $(0, h)$, and (l, l) in Period 2, implying $2l < h$ and $\tilde{u}_F = \delta(1 - h)$. Note that each Period 2 proposal will pass if at least one responder is low, and thus $u_1 + u_2 \leq \max\{2l, h\} = h$. P's Period 2 indifference also implies that $\tilde{\mu}_{iL} < 1$, and so $x_i \leq (1 - \delta)l + \delta u_i^L$, for $i = 1, 2$. Therefore, $x_1 + x_2 \leq (1 - \delta)2l + \delta(u_1 + u_2) \leq (1 - \delta)2l + \delta h < h$, and so $u_P = 1 - (x_1 + x_2) \geq 1 - h > \delta(1 - h) = \tilde{u}_F$, a contradiction.

It follows that $\tilde{u}_F > \hat{u}_F$. Then the Period 2 proposal in the “tilde” equilibrium is (l, l) for sure. (To see this, note that $\hat{u}_F \geq \delta(1 - h)$ because P can never do worse than offering h to one responder. Thus the only way to achieve $\tilde{u}_F > \hat{u}_F$ is to offer (l, l) .) As in case (b), it follows that $\tilde{\mu}_{iL} < 1$ and $x_1 + x_2 \leq 2l$. Hence $u_P = 1 - x_1 - x_2 \geq 1 - 2l$. Further, $\tilde{u}_F = \delta(1 - 2l) \left(1 - \frac{1}{2 - \tilde{\mu}_{1l}} \frac{1}{2 - \tilde{\mu}_{2l}}\right)$. Since P could offer (l, l) in Period 2 in the “hat” equilibrium, we must have $\hat{u}_F \geq \delta(1 - 2l) \left(1 - \frac{1}{2 - \hat{\mu}_{1l}} \frac{1}{2 - \hat{\mu}_{2l}}\right)$. Next, it is easy to verify that the probability of Period 1 agreement in the “tilde” equilibrium is $\tilde{p} = 1 - \frac{(2 - \tilde{\mu}_{1l})(2 - \tilde{\mu}_{2l})}{4}$ and that therefore $(1 - \tilde{p})\tilde{u}_F = \left(\frac{3}{4} - \tilde{p}\right)\delta(1 - 2l)$.¹⁸ Similarly $(1 - \hat{p})\hat{u}_F \geq \left(\frac{3}{4} - \hat{p}\right)\delta(1 - 2l)$.

¹⁸The probability of Period 1 agreement is the probability that not both responders vote N:

$$\begin{aligned} p &= 1 - \left[\frac{1}{2} + \frac{1 - \mu_1^L}{2} \right] \left[\frac{1}{2} + \frac{1 - \mu_2^L}{2} \right] \\ &= 1 - \left[\frac{2 - \mu_1^L}{2} \right] \left[\frac{2 - \mu_2^L}{2} \right] \end{aligned}$$

and thus

$$\begin{aligned} (1 - p) \left(1 - \frac{1}{2 - \mu_1^L} \frac{1}{2 - \mu_2^L}\right) &= \frac{(2 - \tilde{\mu}_{1l})(2 - \tilde{\mu}_{2l})}{4} \left(1 - \frac{1}{2 - \mu_1^L} \frac{1}{2 - \mu_2^L}\right) \\ &= \frac{(2 - \tilde{\mu}_{1l})(2 - \tilde{\mu}_{2l})}{4} - \frac{1}{4} \\ &= 1 - \tilde{p} - \frac{1}{4} = \frac{3}{4} - \tilde{p} \end{aligned}$$

Hence

$$\begin{aligned}
(1 - \tilde{p}) \tilde{u}_F - (1 - \hat{p}) \hat{u}_F &\leq \left[\left(\frac{3}{4} - \tilde{p} \right) - \left(\frac{3}{4} - \hat{p} \right) \right] \delta (1 - 2l) \\
&= (\hat{p} - \tilde{p}) \delta (1 - 2l) \\
&< (\hat{p} - \tilde{p}) u_P.
\end{aligned}$$

Thus $(\hat{p} - \tilde{p}) u_P > (1 - \tilde{p}) \tilde{u}_F - (1 - \hat{p}) \hat{u}_F$, a contradiction.

1.B Unanimity rule

1.B.1 Period 2 proposal (unanimity rule)

Suppose without loss of generality that $\omega_1 \leq \omega_2$. It can be shown that the optimal Period 2 proposal is given by

$$x_2(\omega_1, \omega_2) = \begin{cases} (l, l) & \text{if } \omega_2 < \frac{\tau}{1-2l}, \\ (h, h) & \text{if } \omega_1 > \frac{\tau}{1-l-h}, \\ (l, h) & \text{if } \omega_2 > \frac{\tau}{1-2l} \text{ and } \omega_1 < \frac{\tau}{1-l-h}. \end{cases}$$

1.B.2 Period 1 voting (unanimity rule)

We apply the algorithm described in the main text to characterize continuation equilibria following Period 1 proposals allocating strictly less than h to both responders. Recall that high types vote N on all such proposals. Thus, all acceptance probability vectors are of the form $\mu = (\mu_1^L, 0, \mu_2^L, 0)$. We therefore focus on *low type* acceptance probability vectors $(\mu_1^L, \mu_2^L) \in [0, 1]^2$.

Acceptance vector $\mu^L = (0, 0)$ It is easy to see that this is consistent with *any proposal* that allocates strictly less than h to both responders.

Acceptance vector $\mu^L = (\mu_1^L, 0)$ **with** $\mu_1^L \neq 0$ Then we have (2) $\omega^{NN} = \left(\frac{1}{2-\mu_1^L}, \frac{1}{2}\right)$, $\omega^{YN} = (0, \frac{1}{2})$ and $\omega^{NY} = (1, 0)$, and (3) the relevant continuation values are $u_1^{YN} = l$ and $u_1^{NN} = h$ if $\tau < \hat{\tau}^u$, and $u_1^{NN} = \frac{h+l}{2}$ if $\tau > \hat{\tau}^u$. But (4) $\mu_1^L > 0$ requires (given $\mu_2^L = 0$) $u_1^{YN} \geq u_1^{NN}$, a contradiction. Thus such acceptance probability vector are *not consistent with any proposal*. (The intuition is that when R2 votes N for sure, the proposal will fail anyway and so R1 cannot possibly accept, since all this does is reveal his low type.)

We can summarize the previous two observations as follows.

Lemma 8. Certain rejection by both responders constitutes a continuation equilibrium following any Period 1 proposal that allocates strictly less than h to both responders. All other equilibria involve both players voting Y with positive probability as low types.

The corresponding area of Period 1 proposals x_1 such that there exists a continuation equilibrium involving the acceptance probability vectors $\mu^L = (0, 0, 0, 0)$ thus is

$$A(0, 0, 0, 0) = \text{conv} \{(0, 0), (0, h), (h, h), (h, 0)\}.$$

Acceptance vector $\mu^L = (1, 1)$ This was presented as an example in the main text. We showed there that such continuation equilibria exist if

$$x_i \geq l + 2\delta(h - l) \text{ for } i = 1, 2,$$

which is consistent with $x_i < h$ only if $\delta < \frac{1}{2}$. If so, these equilibria exist within

$$A(1, 0, 1, 0) = \text{conv} \{(l + 2\delta(h - l), l + 2\delta(h - l)), (l + 2\delta(h - l), h), (h, h), (h, l + 2\delta(h - l))\}.$$

Profiles involving mixing To analyse profiles involving mixing, it will be convenient to separately consider the cases $\tau < \hat{\tau}^u$ and $\tau > \hat{\tau}^u$. The first of these is simple because the Period 2 proposal will always allocate h to a responder who voted N in Period 1, and

l to a responder who voted Y. As we will see, the area in which mixed equilibria exist is then identical to the area in which the $\mu^L = (1, 1)$ equilibrium exists. This will imply that we can disregard these equilibria later in our analysis.

Assume $\tau < \hat{\tau}^u$ **and consider** $\mu^L = (\mu_1^L, 1)$ **with** $\mu_1^L \in (0, 1)$. Then (1) $\omega^{NN} = (\omega_1^N, 1)$, $\omega^{YN} = (0, 1)$ and $\omega^{NY} = (\omega_1^N, 0)$ where $\omega_1^N > \bar{\omega}$, so that P offers h or l in Period 2 depending on whether a responder voted N or Y , and that proposal passes. Thus (2) $(u_1^{NN}, u_2^{NN}, u_1^{YN}, u_2^{YN}, u_1^{NY}, u_2^{NY}) = (h, h, l, h, h, l)$. Then (3) $\mu_1^L \in (0, 1)$ requires that

$$x_1 = l + 2\delta(h - l)$$

and $\mu_2^L = 1$ requires that

$$x_2 \geq l + \frac{2\delta}{\mu_1^L} (h - l).$$

For $x_2 \leq h$ we need $\mu_1^L > 2\delta$, requiring $\delta < \frac{1}{2}$. If so, such equilibria exist for each $\mu_1^L \in (2\delta, 1)$. For each such value, the equilibria exist within a line segment

$$A(\mu_1^L, 0, 1, 0) = \text{conv} \left\{ \left(l + 2\delta(h - l), l + \frac{2\delta}{\mu_1^L} (h - l) \right), (l + 2\delta(h - l), h) \right\}.$$

Given $\mu_1^L \in (2\delta, 1)$, this line is a subset of the line connecting $(l + 2\delta(h - l), l + 2\delta(h - l))$ and $(l + 2\delta(h - l), h)$. At each point strictly inside that line segment, there are multiple such equilibria, involving $\mu_1^L \in \left[2\delta \left(\frac{h-l}{x_2-l} \right), 1 \right)$. Note that this line segment is exactly equal to the left boundary to the (closed) area in which the $\mu^L = (1, 1)$ equilibrium exists. Thus, for each $\mu_1^L \in (2\delta, 1)$, $A(\mu_1^L, 0, 1, 0) \subset A(1, 0, 1, 0)$.

Assume $\tau < \hat{\tau}^u$ **and consider** $\mu^L = (\mu_1^L, \mu_2^L)$ **with both** $\mu_i^L \in (0, 1)$. Then, (1) $\omega^{NN} = (\omega_1^N, \omega_2^N)$, $\omega^{YN} = (0, \omega_2^N)$ and $\omega^{NY} = (\omega_1^N, 0)$ where both $\omega_i^N > \bar{\omega}$. Any re-

sponder voting N (Y) is offered h (l) in Period 2, and that proposal will pass. So (2) $(u_1^{NN}, u_2^{NN}, u_1^{YN}, u_2^{NY}, u_1^{NY}, u_2^{YN}) = (h, h, l, h, h, l)$ and hence (3) $\mu_i^L \in (0, 1)$ requires

$$x_i = l + \frac{2\delta}{\mu_{-iL}} (h - l).$$

This is less than h iff $\mu_{-iL} > 2\delta$, requiring $\delta < \frac{1}{2}$. If so, equilibria involving the responders to vote Y with fixed probabilities $\mu_1^L \in (2\delta, 1)$ and $\mu_2^L \in (2\delta, 1)$ only exist at

$$A(\mu_1^L, 0, \mu_2^L, 0) = \left(l + \frac{2\delta}{\mu_1^L} (h - l), l + \frac{2\delta}{\mu_1^L} (h - l) \right).$$

Such equilibria (when varying the voting Y probabilities over the interval $(2\delta, 1)$) exist within $\text{conv} \{(l + 2\delta(h - l), l + 2\delta(h - l)), (l + 2\delta(h - l), h), (h, h), (h, l + 2\delta(h - l))\}$. At each point within this area, $\mu_i^L = 2\delta \left(\frac{h-l}{x_{-i}-l} \right)$. Note that this is decreasing in the share allocated to the other responder, approaching 1 for x_{-i} close to $l + 2\delta(h - l)$ and approaching 2δ as x_{-i} approaches h . Note that this rectangle is identical to $A(1, 0, 1, 0)$ and thus, for all combinations of $\mu_1^L \in (2\delta, 1)$ and $\mu_2^L \in (2\delta, 1)$, $A(\mu_1^L, 0, \mu_2^L, 0) \subset A(1, 0, 1, 0)$.

Assume from now on that $\tau > \hat{\tau}^u$. In this case, it is useful to define a specific acceptance probability, denoted

$$\bar{\mu} = 1 - \frac{1 - 2h}{h - l} = \frac{3h - l - 1}{h - l},$$

with the property that if $\mu_i^L = \bar{\mu}$, then $\omega_{iN} = \bar{\omega} = \frac{h-l}{1-h-l}$. This is relevant because the Period 2 proposals following failure depend on whether $\omega_{iN} \leq \bar{\omega}$. (See right panel of Figure 4.)

Acceptance vector $\mu^L = (\mu_1^L, 1)$ with $\mu_1^L \in (\bar{\mu}, 1)$ Then the analysis is the same as for $\tau < \hat{\tau}^u$, above, except that an additional condition is that μ_1^L must be larger than $\bar{\mu}$. That is, such equilibria exist iff $\delta < \frac{1}{2}$. If so, they exist within

$$A(\mu_1^L, 0, 1, 0) = \text{conv} \left\{ \left(l + 2\delta(h-l), l + \frac{2\delta}{\mu_1^L}(h-l) \right), (l + 2\delta(h-l), h) \right\}.$$

At each point along this line segment, there are multiple such equilibria, with $\mu_1^L \in \left[\max \left\{ \bar{\mu}, 2\delta \left(\frac{h-l}{x_2-l} \right) \right\}, 1 \right)$. Again, for each $\mu_1^L \in (\max \{ \bar{\mu}, 2\delta \}, 1)$, $A(\mu_1^L, 0, 1, 0) \subset A(1, 0, 1, 0)$.

Acceptance vector $\mu^L = (\bar{\mu}, 1)$ Then (1) $\omega^{NN} = (\omega_1^N, 1)$, $\omega^{YN} = (0, 1)$ and $\omega^{NY} = (\omega_1^N, 0)$, where $\omega_1^N = \frac{1}{2-\mu_1^L} = \bar{\omega}$. Following NN, P is indifferent between (l, h) and (h, h) . Suppose in this case P offers (h, h) with probability ρ and (l, h) with $1 - \rho$. Then (2)

$$(u_1^{NN}, u_{2L}^{NN}, u_1^{YN}, u_2^{NY}, u_1^{NY}, u_2^{YN}) = (l + \rho(h-l), h - \frac{1-\rho}{2-\mu_1^L}(h-l), l, h, h, l).$$

Then (3) $\mu_1^L = \bar{\mu} \in (0, 1)$ requires

$$x_1 = l + \delta(1 + \rho)(h-l),$$

and $\mu_2^L = 1$ requires

$$x_2 \geq l + \delta \left[\frac{1+\rho}{\bar{\mu}} \right] (h-l).$$

This type of equilibrium exists within the line segment connecting the two points $\left(l + \delta(1 + \rho)(h-l), l + \delta \left[\frac{1+\rho}{\bar{\mu}} \right] (h-l) \right)$ and $(l + \delta(1 + \rho)(h-l), h)$. Such line segment exists if $\delta(1 + \rho) < \bar{\mu}$, requiring $\bar{\mu} > \delta$. If so, then every ρ satisfying $\rho < \frac{\bar{\mu}-\delta}{\delta}$ will be associated with such a line segment. At $\rho = 0$, it connects the points $\left(l + \delta(h-l), l + \frac{\delta}{\bar{\mu}}(h-l) \right)$ and $(l + \delta(h-l), h)$. At $\rho = \frac{\bar{\mu}-\delta}{\delta}$, it collapses down to the single point $(l + \bar{\mu}(h-l), h)$. As ρ varies between these extremes, we obtain a triangle and thus the equilibrium exists

within

$$A(\bar{\mu}, 0, 1, 0) = \text{conv} \left\{ \left(l + \delta(h-l), l + \frac{\delta}{\bar{\mu}}(h-l) \right), (l + \delta(h-l), h), (l + \bar{\mu}(h-l), h) \right\}.$$

At each point within this area, the associated equilibrium involves $\rho = \frac{1}{\delta} \frac{x_1 - l}{h-l} - 1$. At the corner $\left(l + \delta(h-l), l + \frac{\delta}{\bar{\mu}}(h-l) \right)$, we have $\rho = 0$, and likewise along the line segment to $(l + \delta(h-l), h)$. At the corner $(l + \bar{\mu}(h-l), h)$, we have $\rho = \frac{\bar{\mu} - \delta}{\delta}$.

Acceptance vector $\mu^L = (\mu_1^L, 1)$ **with** $\mu_{jL} \in (0, \bar{\mu})$ Then (1) $\omega^{NN} = (\omega_1^N, 1)$, $\omega^{YN} = (0, 1)$ and $\omega^{NY} = (\omega_1^N, 0)$, where $\omega_1^N = \frac{1}{2 - \mu_1^L} < \bar{\omega}$. Following NN, P offers (l, h) and so (2) $(u_1^{NN}, u_2^{NN}, u_1^{YN}, u_2^{NY}, u_1^{NY}, u_2^{YN}) = (l, h - \omega_1^N(h-l), l, h, h, l)$. Thus (3) $\mu_1^L \in (0, \bar{\mu})$ requires that

$$x_1 = l + \delta(h-l),$$

and $\mu_2^L = 1$ requires that

$$x_2 \geq l + \frac{\delta}{\mu_1^L}(h-l).$$

For a fixed $\mu_1^L < \bar{\mu}$, equilibria of this type exist within

$$A(\mu_1^L, 0, 1, 0) = \text{conv} \left\{ \left(l + \delta(h-l), l + \frac{\delta}{\mu_1^L}(h-l) \right), (l + \delta(h-l), h) \right\}.$$

This line segment exists if $\mu_1^L > \delta$ requiring $\bar{\mu} > \delta$. If so, such equilibria exist for all $\mu_1^L \in (\delta, \bar{\mu})$, and along a line segment connecting $\left(l + \delta(h-l), l + \frac{\delta}{\bar{\mu}}(h-l) \right)$ and $(l + \delta(h-l), h)$. At a given point, μ_1^L can take on any value $\mu_1^L \in \left[\delta \left(\frac{h-l}{x_2-l} \right), \bar{\mu} \right)$. For each $\mu_1^L \in (\delta, \bar{\mu})$, $A(\mu_1^L, 0, 1, 0) \subset A(\bar{\mu}, 0, 1, 0)$.

Acceptance vector $\mu^L = (\mu_1^L, \mu_2^L)$ **with both** $\mu_i^L \in (\bar{\mu}, 1)$ Then (1) $\omega_i^N > \bar{\omega}$ for both i , and so as in the case $\tau < \hat{\tau}^u$, $(u_1^{NN}, u_2^{NN}, u_1^{YN}, u_2^{NY}, u_1^{NY}, u_2^{YN}) = (h, h, l, h, h, l)$

and (3) $x_i = l + \frac{2\delta}{\mu_{-iL}}(h-l)$, requiring $\mu_i > 2\delta$. So, given $\mu_1^L \in (\max\{\bar{\mu}, 2\delta\}, 1)$ and $\mu_2^L \in (\max\{\bar{\mu}, 2\delta\}, 1)$, the equilibrium exists at

$$A(\mu_1^L, 0, \mu_2^L, 0) = \left(l + \frac{2\delta}{\mu_2^L}(h-l), l + \frac{2\delta}{\mu_1^L}(h-l) \right).$$

By varying the voting Y probabilities, we obtain the area in which such types of equilibria exist: $\text{conv}\{(l + 2\delta(h-l), l + 2\delta(h-l)), (l + 2\delta(h-l), h), (h, h), (h, l + 2\delta(h-l))\}$ if $\bar{\mu} < 2\delta$ and

$$\begin{aligned} \text{conv}\{(l + 2\delta(h-l), l + 2\delta(h-l)), (l + 2\delta(h-l), h), \\ (l + \frac{2\delta}{\bar{\mu}}(h-l), l + \frac{2\delta}{\bar{\mu}}(h-l)), (h, l + 2\delta(h-l))\} \end{aligned}$$

if $\bar{\mu} > 2\delta$. At each point within this area, $\mu_i^L = 2\delta \left(\frac{h-l}{x_{-i}-l} \right)$. Again, for each combination of $\mu_1^L \in (\max\{\bar{\mu}, 2\delta\}, 1)$ and $\mu_2^L \in (\max\{\bar{\mu}, 2\delta\}, 1)$, $A(\mu_1^L, 0, \mu_2^L, 0) \subset A(1, 0, 1, 0)$.

Acceptance vector $\mu^L = (\mu_1^L, \mu_2^L)$ **with** $0 < \mu_1^L < \mu_2^L < \bar{\mu}$ Then (1) $\frac{1}{2} < \omega_1^N < \omega_2^N < \bar{\omega}$. P offers (l, h) following NN. Thus (2)

$$(u_1^{NN}, u_{2L}^{NN}, u_1^{YN}, u_2^{NY}, u_1^{NY}, u_2^{YN}) = \left(l, h - \frac{h-l}{2 - \mu_1^L}, l, h, h, l \right).$$

Then (3) mixing by both responders requires

$$x_1 = l + \delta(h-l)$$

and

$$x_2 = l + \frac{\delta}{\mu_1^L}(h-l).$$

Then $x_2 < h$ requires $\mu_1^L > \delta$. Thus, given $\mu_1^L \in (\delta, \bar{\mu})$, the equilibrium exists at

$$A(\mu_1^L, 0, \mu_2^L, 0) = \left(l + \delta(h - l), l + \frac{\delta}{\mu_1^L}(h - l) \right).$$

By varying the voting Y probabilities, we obtain the area in which such types of equilibria exist: $\text{conv} \left\{ \left(l + \delta(h - l), l + \frac{\delta}{\bar{\mu}}(h - l) \right), (l + \delta(h - l), h) \right\}$. (These equilibria exist *strictly* between those points.) At each point, $\mu_1^L = \delta \left(\frac{h-l}{x_2-l} \right)$ and $\mu_2^L \in (\mu_1^L, \bar{\mu})$. For each combination of $\mu_1^L \in (\delta, \bar{\mu})$ and $\mu_2^L \in (\mu_1^L, \bar{\mu})$, $A(\mu_1^L, 0, \mu_2^L, 0) \subset A(\bar{\mu}, 0, 1, 0)$.

Acceptance vector $\mu^L = (\mu_1^L, \mu_2^L)$ **with** $0 < \mu_1^L = \mu_2^L = \mu < \bar{\mu}$ Then (1) $\omega_1^N = \omega_2^N \in (\frac{1}{2}, \bar{\omega})$. P is indifferent between (l, h) and (h, l) following NN. Assume he offers (h, l) with prob ρ . Then (2)

$$(u_1^{NN}, u_{2L}^{NN}, u_1^{YN}, u_2^{NY}, u_1^{NY}, u_2^{YN}) = \left(l + \rho \frac{1-\mu}{2-\mu}(h-l), l + (1-\rho) \frac{1-\mu}{2-\mu}(h-l), l, h, h, l \right).$$

Then (3) mixing by both responders requires

$$\begin{aligned} x_1 &= l + \left(1 + \rho \frac{1-\mu}{\mu} \right) \delta(h-l), \\ x_2 &= l + \left(1 + (1-\rho) \frac{1-\mu}{\mu} \right) \delta(h-l). \end{aligned}$$

For $x_i < h$, we need $\frac{\delta\rho}{1-\delta(1-\rho)} < \mu$ and $\frac{\delta(1-\rho)}{1-\delta\rho} < \mu$. I.e., a necessary condition for equilibria of this type to exist is that there exists $\rho \in [0, 1]$ such that $\mu > \max \left\{ \frac{\delta\rho}{1-\delta(1-\rho)}, \frac{\delta(1-\rho)}{1-\delta\rho} \right\}$. The first lower bound is increasing and the second decreasing in ρ , and they are completely symmetric. For a given μ , the inequality can therefore hold at *some* ρ iff it holds for $\rho = \frac{1}{2}$, giving the condition

$$\mu > \frac{\delta}{2-\delta},$$

which in turn is compatible with $\mu < \bar{\mu}$ iff

$$\frac{\delta}{2-\delta} < \frac{3h-l-1}{h-l}.$$

Under the last condition, there exist μ and ρ such that these type of equilibria exist. If so, the possible range for μ is $\left(\frac{\delta}{2-\delta}, \bar{\mu}\right)$. For each μ in this range, there is a range for ρ such that both $x_i < h$. This is $\rho \in [0, 1]$ if $\delta < \mu$ and $\rho \in \left(\frac{\delta-\mu}{\delta(1-\mu)}, \frac{\mu}{1-\mu} \frac{1-\delta}{\delta}\right)$ if $\delta \geq \mu$, which is nonempty given $\mu > \frac{\delta}{2-\delta}$. At $\mu = \frac{\delta}{2-\delta}$, that line segment collapses to the single point (h, h) . Thus, given $\mu \in (\frac{\delta}{2-\delta}, \delta)$, the equilibrium exists within (at $\mu = \frac{\delta}{2-\delta}$, the line segment collapses to the single point (h, h))

$$A(\mu, 0, \mu, 0) = \text{conv} \left\{ \left(l + \left(1 + \frac{\delta - \mu}{\mu \delta} \right) \delta (h - l), h \right), \left(h, l + \left(1 + \frac{\delta - \mu}{\mu \delta} \right) (h - l) \right) \right\},$$

and given $\mu \in (\delta, \bar{\mu})$, within

$$A(\mu, 0, \mu, 0) = \left\{ \left(l + \delta (h - l), l + \frac{\delta}{\mu} (h - l) \right), \left(l + \frac{\delta}{\mu} (h - l), l + \delta (h - l) \right) \right\}.$$

If $\bar{\mu} < \delta$, then, as μ increases, the line segments are all diagonals sloping down within the square to the southwest of (h, h) . At $\mu = \bar{\mu}$, the last such line connects the two points $\left(l + \left(1 + \frac{\delta - \bar{\mu}}{\bar{\mu} \delta} \right) \delta (h - l), h \right)$ and $\left(h, l + \left(1 + \frac{\delta - \bar{\mu}}{\bar{\mu} \delta} \right) \delta (h - l) \right)$. In that case we obtain a triangle with corners given by those two points and (h, h) . If $\bar{\mu} > \delta$, then at $\mu = \delta$ the line segment connects the points $(l + \delta (h - l), h)$ and $(h, l + \delta (h - l))$, and as μ increases further it eventually connects $\left(l + \delta (h - l), l + \frac{\delta}{\mu} (h - l) \right)$ and $\left(l + \frac{\delta}{\mu} (h - l), l + \delta (h - l) \right)$. So in this case we obtain a pentagon which is the convex hull of those four points and (h, h) . (A simpler way to describe this may be that it is the area where both $x_i \in (l + \delta(h - l), h)$ and $x_1 + x_2 > l + h + \delta(h - l)$.) Equilibria of this type exist in the interior of the area. At

each such point, μ is determined by the sum of offers $x_1 + x_2$:

$$\mu = \frac{\delta(h-l)}{x_1 + x_2 - 2l - \delta(h-l)}.$$

(Note that, paradoxically, the acceptance probability is *decreasing* in the sum of offers.) ρ is likewise determined but irrelevant for our subsequent analysis because P's EU is independent of ρ .

Acceptance vector $\mu^L = (\bar{\mu}, \mu_2^L)$ **with** $\mu_2^L \in (\bar{\mu}, 1)$ Then (1) $\omega^{NN} = (\bar{\omega}, \omega_2^N)$ with $\omega_2^N > \bar{\omega}$. Following NN, P is indifferent between (l, h) and (h, h) . Suppose she proposes (h, h) with probability ρ . Then (2)

$$(u_1^{NN}, u_{2L}^{NN}, u_1^{YN}, u_2^{NY}, u_1^{NY}, u_2^{YN}) = \left(l + \rho(h-l), h - \frac{1-\rho}{2-\bar{\mu}}(h-l), l, h, h, l \right).$$

Therefore, (3) mixing by both responders requires

$$\begin{aligned} x_1 &= l + \left[1 + \frac{2-\mu_2^L}{\mu_2^L} \rho \right] \delta(h-l), \\ x_2 &= l + \frac{1+\rho}{\bar{\mu}} \delta(h-l). \end{aligned}$$

It is easy to verify that $x_2 > x_1$. Then $x_i < h$ requires $\rho < \frac{\bar{\mu}-\delta}{\delta}$, giving us the necessary condition $\delta < \bar{\mu}$ and the range $\rho \in \left(0, \min\left\{\frac{\bar{\mu}-\delta}{\delta}, 1\right\}\right)$. So, given $\mu_2^L \in (\bar{\mu}, 1)$ and $\delta < \bar{\mu}/2$, the equilibrium exists within

$$A(\mu, 0, \mu, 0) = \text{conv} \left\{ \left(l + \delta(h-l), l + \frac{\delta}{\bar{\mu}}(h-l) \right), \left(l + \frac{2\delta}{\mu_2^L}(h-l), l + \frac{2\delta}{\bar{\mu}}(h-l) \right) \right\},$$

and, given $\mu_2^L \in (\bar{\mu}, 1)$ and $\delta \geq \bar{\mu}/2$, within

$$A(\mu, 0, \mu, 0) = \text{conv} \left\{ \left(l + \delta(h-l), l + \frac{\delta}{\bar{\mu}}(h-l) \right), \left(l + \frac{2\delta}{\mu_2^L}(h-l), l + \frac{2\delta}{\bar{\mu}}(h-l) \right) \right\}.$$

If $\delta < \bar{\mu}/2$, varying $\mu_2^L \in (\bar{\mu}, 1)$ gives us a triangle with corners $(l + \delta(h-l), l + \frac{\delta}{\bar{\mu}}(h-l))$, $(l + \frac{2\delta}{\bar{\mu}}(h-l), l + \frac{2\delta}{\bar{\mu}}(h-l))$, and $(l + 2\delta(h-l), l + \frac{2\delta}{\bar{\mu}}(h-l))$. Similarly, if $\delta \in (\bar{\mu}/2, \bar{\mu})$, varying $\mu_2^L \in (\bar{\mu}, 1)$ gives us a triangle with the corners $(l + \delta(h-l), l + \frac{\delta}{\bar{\mu}}(h-l))$, $(l + [1 + \frac{2-\bar{\mu}}{\bar{\mu}} \frac{\bar{\mu}-\delta}{\delta}] \delta(h-l), h)$, and $(l + \bar{\mu}\delta(h-l), h)$. At each point within this area, the associated probabilities are determined by the equations for x_i above:

$$\begin{aligned}\mu_2^L &= 2 \frac{\bar{\mu}(x_2 - l) - \delta(h-l)}{\bar{\mu}(x_2 - l) + (x_1 - l)}, \\ \rho &= \frac{\bar{\mu} x_2 - l}{\delta(h-l)} - 1.\end{aligned}$$

Acceptance vector $\mu^L = (\bar{\mu}, \bar{\mu})$ Then (1) $\omega^{NN} = (\bar{\omega}, \bar{\omega})$ and P is indifferent between (l, h) , (h, l) , and (h, h) following NN. Suppose in this case he offers (h, l) with prob ρ , (l, h) with γ and (h, h) with $1 - \rho - \gamma$. Then (2)

$$(u_1^{NN}, u_{2L}^{NN}, u_1^{YN}, u_2^{NY}, u_1^{NY}, u_2^{YN}) = \left(h - (\gamma + \frac{\rho}{2 - \bar{\mu}})(h-l), h - (\rho + \frac{\gamma}{2 - \bar{\mu}})(h-l), l, h, h, l \right).$$

Then (3) mixing by both responders requires

$$\begin{aligned}x_1 &= l + (2 - \rho - \gamma - (1 - \bar{\mu})\gamma) \frac{\delta}{\bar{\mu}}(h-l), \\ x_2 &= l + (2 - \rho - \gamma - (1 - \bar{\mu})\rho) \frac{\delta}{\bar{\mu}}(h-l).\end{aligned}$$

Then $x_i < h$ requires

$$\frac{\bar{\mu}}{\delta} > 2 - \rho - \gamma - (1 - \bar{\mu}) \min\{\gamma, \rho\}.$$

For a given sum $\rho + \gamma$, the best chance to satisfy this is $\rho = \gamma$, in which case it can be satisfied iff there exists $\rho \in (0, \frac{1}{2})$ such that $\frac{\bar{\mu}}{\delta} > 2 - (3 - \bar{\mu})\rho$. Here, the best case is $\rho = \frac{1}{2}$. Thus, a necessary and sufficient condition for the existence of such equilibria is

$\frac{\bar{\mu}}{\delta} > \frac{1}{2} + \bar{\mu}/2$, or

$$\delta < \frac{2\bar{\mu}}{\bar{\mu} + 1}.$$

If so, the region in which these equilibria exist is non-empty. The region arises by varying ρ and γ . If $\delta < \bar{\mu}/2$, the northeast corner of the triangle that characterizes the equilibrium points arises from the case where P always offers (h, h) in Period 2, i.e., $(\rho, \gamma) = (0, 0)$, leading to the point $\left(l + \frac{2\delta}{\bar{\mu}}(h - l), l + \frac{2\delta}{\bar{\mu}}(h - l)\right)$. The triangle is completed by the corners where $(\rho, \gamma) = (1, 0)$ and $(\rho, \gamma) = (0, 1)$ and thus the equilibrium, given $\delta < \bar{\mu}/2$, exists within

$$A(\bar{\mu}, 0, \bar{\mu}, 0) = \text{conv} \left\{ \left(l + \delta(h - l), l + \frac{\delta}{\bar{\mu}}(h - l) \right), \left(l + \frac{2\delta}{\bar{\mu}}(h - l), l + \frac{2\delta}{\bar{\mu}}(h - l) \right), \left(l + \frac{\delta}{\bar{\mu}}(h - l), l + \delta(h - l) \right) \right\}.$$

If $\delta \in (\bar{\mu}/2, \bar{\mu})$, then $(\rho, \gamma) = (0, 0)$ is not feasible (it would require $x_i > h$). Consequently, the northeast corner now is (h, h) . The upper corner to the west of (h, h) is where $x_2 = h$ and $\rho = 0$, leading to $\left(h - \frac{(2\delta - \bar{\mu})(1 - \bar{\mu})}{\bar{\mu}}(h - l), h\right)$. By symmetry, the corner to the south of (h, h) is where $x_1 = h$ and $\gamma = 0$, leading to $\left(h, h - \frac{(2\delta - \bar{\mu})(1 - \bar{\mu})}{\bar{\mu}}(h - l)\right)$. The other two corners in the southwest stay as before and thus the equilibrium, given $\delta \in (\bar{\mu}/2, \bar{\mu})$, exists within

$$A(\bar{\mu}, 0, \bar{\mu}, 0) = \text{conv} \left\{ \left(l + \delta(h - l), l + \frac{\delta}{\bar{\mu}}(h - l) \right), \left(h - \frac{(2\delta - \bar{\mu})(1 - \bar{\mu})}{\bar{\mu}}(h - l), h \right), (h, h), \left(l + \frac{2\delta}{\bar{\mu}}(h - l), l + \frac{2\delta}{\bar{\mu}}(h - l) \right), \left(h, h - \frac{(2\delta - \bar{\mu})(1 - \bar{\mu})}{\bar{\mu}}(h - l) \right), \left(l + \frac{\delta}{\bar{\mu}}(h - l), l + \delta(h - l) \right) \right\}.$$

If $\delta \in \left(\bar{\mu}, \frac{2\bar{\mu}}{\bar{\mu} + 1}\right)$, the northeast corner again is (h, h) . Now, $(\rho, \gamma) = (1, 0)$ and $(\rho, \gamma) = (0, 1)$ are not feasible as they would require $x_2 > h$ and $x_1 > h$, respectively. The upper corner to the west of (h, h) is where $x_2 = h$ and $\rho + \gamma = 1$ (note that $x_1 + x_2 = 2l + \delta \frac{1 + \bar{\mu}}{\bar{\mu}}(h - l)$ if

$\rho + \gamma = 1$), leading to $\left(l + \left(\delta \frac{1+\bar{\mu}}{\bar{\mu}} - 1\right)(h-l), h\right)$. By symmetry, the corner to the south of (h, h) is where $x_1 = h$ and $\rho + \gamma = 1$, leading to $\left(h, l + \left(\delta \frac{1+\bar{\mu}}{\bar{\mu}} - 1\right)(h-l)\right)$. Thus the equilibrium, given $\delta \in \left(\bar{\mu}, \frac{2\bar{\mu}}{\bar{\mu}+1}\right)$, exists within

$$A(\bar{\mu}, 0, \bar{\mu}, 0) = \text{conv} \left\{ \left(l + \left(\delta \frac{1+\bar{\mu}}{\bar{\mu}} - 1 \right) (h-l), h \right), (h, h), \right. \\ \left. \left(h, l + \left(\delta \frac{1+\bar{\mu}}{\bar{\mu}} - 1 \right) (h-l) \right) \right\}.$$

To sum up, each of these areas are part of the triangle that can be described by the convex hull

$$\text{conv} \left\{ \left(l + \delta(h-l), l + \frac{\delta}{\bar{\mu}}(h-l) \right), \left(l + \frac{2\delta}{\bar{\mu}}(h-l), l + \frac{2\delta}{\bar{\mu}}(h-l) \right), \right. \\ \left. \left(l + \frac{\delta}{\bar{\mu}}(h-l), l + \delta(h-l) \right) \right\}.$$

There, the conditions $x_1 < h$ and $x_2 < h$ determine the size of the triangle where an equilibrium with an acceptance vector of $\mu = (\bar{\mu}, 0, \bar{\mu}, 0)$ exists. At each point within these areas, the associated probabilities are $\rho = \frac{2(1-\bar{\mu})\delta(h-l) + \bar{\mu}(x_1 - 2x_2 + l + \bar{\mu}(x_2 - l))}{(3-\bar{\mu})(1-\bar{\mu})\delta(h-l)}$ and $\gamma = \frac{2(1-\bar{\mu})\delta(h-l) + \bar{\mu}(x_2 - 2x_1 + l + \bar{\mu}(x_1 - l))}{(3-\bar{\mu})(1-\bar{\mu})\delta(h-l)}$ (determined by the equations for x_i above).

1.B.3 Selection of voting equilibria (unanimity rule)

P generally prefers the equilibrium with the larger acceptance probability. If she does not, then she will not make such proposals in Period 1. This we will show below. We exclude equilibrium areas that are fully included in another equilibrium area that is associated with a larger probability of passage and where (at least) at the “cheapest” points of the equilibrium area associated with the lower probability of passage, P indeed prefers the equilibrium with the larger probability of passage:

- $A(\mu_1^L, 0, 1, 0) \subset A(\bar{\mu}, 0, 1, 0)$ for all $\mu_1^L \in (\delta, \bar{\mu})$ and for each of the cheapest points

of $A(\mu_1^L, 0, 1, 0)$ where $\mu_1^L \in (\delta, \bar{\mu})$, P prefers the continuation equilibrium associated with $\mu = (\bar{\mu}, 0, 1, 0)$:

Suppose $\tilde{x}^1 \in A(\tilde{\mu}, 0, 1, 0) = \text{conv} \left\{ \left(l + \delta(h-l), l + \frac{\delta}{\tilde{\mu}}(h-l) \right), (l + \delta(h-l), h) \right\}$.

Then at the cheapest of such equilibria, we have

$EU_P(\tilde{x}^1, \tilde{\mu}) = \frac{\tilde{\mu}}{4} \left(1 - 2l - \frac{1+\tilde{\mu}}{\tilde{\mu}} \delta(h-l) \right) + \frac{\delta}{2} (1-h-l) + \frac{1}{4} (1-\tilde{\mu}) \delta(1-h-l)$ and $\frac{\partial EU_P(x_1, \tilde{\mu})}{\partial \tilde{\mu}} = \frac{1}{4} (1-2l - \delta(h-l)) - \frac{1}{4} \delta(1-h-l) > 0$, which can easily be shown to be true.

- $A(\mu_1^L, 0, \mu_2^L, 0) \subset A(\bar{\mu}, 0, 1, 0)$ for all combinations of $\mu_1^L \in (\delta, \bar{\mu})$ and $\mu_2^L \in (\mu_1^L, \bar{\mu})$. For $x_1 \in A(\mu_1^L, 0, \mu_2^L, 0) = \left(l + \delta(h-l), l + \frac{\delta}{\mu_1^L}(h-l) \right)$, P prefers the continuation equilibrium associated with $\mu = (\bar{\mu}, 0, 1, 0)$:

$EU_P(x_1, \mu = (\mu_1^L, 0, \tilde{\mu}, 0)) = \frac{\mu_1^L \tilde{\mu}}{4} \left(1 - 2l - \frac{1+\mu_1^L}{\mu_1^L \tilde{\mu}} \delta(h-l) \right) + \frac{\delta}{2} (\tilde{\mu} + \mu_1^L - \mu_1^L \tilde{\mu}) (1-h-l) + (2 - \mu_1^L) (1-\tilde{\mu}) \frac{\delta}{4} (1-h-l)$ and $\frac{\partial EU_P(x_1, \tilde{\mu})}{\partial \tilde{\mu}} = \frac{\mu_1^L}{4} (1-2l) + \frac{\delta}{2} (1-\mu_1^L) (1-h-l) - (2-\mu_1^L) \frac{\delta}{4} (1-h-l) > 0$ which can be shown to be true. Thus P prefers $\mu = (\mu_1^L, 0, 1, 0)$ over $\mu = (\mu_1^L, 0, \tilde{\mu}, 0)$. In addition, we know from above that P prefers $\mu = (\bar{\mu}, 0, 1, 0)$ over $\mu = (\mu_1^L, 0, 1, 0)$ when $\mu_1^L \in (\delta, \bar{\mu})$.

- $A(\mu_1^L, 0, 1, 0) \subset A(1, 0, 1, 0)$ for all $\mu_1^L \in (\max\{\bar{\mu}, 2\delta\}, 1)$. For each of the cheapest points of $A(\mu_1^L, 0, 1, 0)$ where $\mu_1^L \in (\max\{\bar{\mu}, 2\delta\}, 1)$, P prefers the continuation equilibrium associated with $\mu = (1, 0, 1, 0)$: Suppose that

$\tilde{x}^1 \in A(\tilde{\mu}, 0, 1, 0) = \text{conv} \left\{ \left(l + 2\delta(h-l), l + \frac{2\delta}{\tilde{\mu}}(h-l) \right), (l + 2\delta(h-l), h) \right\}$. So at the cheapest of such equilibria, we have $EU_P(\tilde{x}^1, \tilde{\mu}) = \frac{\tilde{\mu}}{4} \left(1 - 2l - 2\frac{1+\tilde{\mu}}{\tilde{\mu}} \delta(h-l) \right) + \frac{\delta}{2} (1-h-l) + \frac{1}{2} \left(1 - \frac{\tilde{\mu}}{2} \right) \delta(1-2h)$ and $\frac{\partial EU_P(x_1, \tilde{\mu})}{\partial \tilde{\mu}} = \frac{1}{4} (1-2l - 2\delta(h-l)) - \frac{1}{4} \delta(1-2h) > 0$ which can easily be shown to be true.

- $A(\mu_1^L, 0, \mu_2^L, 0) \subset A(1, 0, 1, 0)$ for all combinations of $\mu_1^L \in (\max\{\bar{\mu}, 2\delta\}, 1)$ and $\mu_2^L \in (\max\{\bar{\mu}, 2\delta\}, 1)$. For $x_1 \in A(\mu_1^L, 0, \mu_2^L, 0) = \left(l + \frac{2\delta}{\mu_1^L}(h-l), l + \frac{2\delta}{\mu_2^L}(h-l) \right)$, P

prefers the continuation equilibrium associated with $\mu = (1, 0, 1, 0)$: We have

$$EU_P(x_1, \mu = (\mu_1^L, 0, \tilde{\mu}, 0)) = \frac{\mu_1^L \tilde{\mu}}{4} \left(1 - 2l - 2 \frac{\mu_1^L + \tilde{\mu}}{\mu_1^L \tilde{\mu}} \delta(h-l)\right) +$$

$$\frac{\delta}{2} (\tilde{\mu} + \mu_1^L - \mu_1^L \tilde{\mu}) (1 - h - l) + \left(1 - \frac{\mu_1^L}{2}\right) \left(1 - \frac{\tilde{\mu}}{2}\right) \delta(1 - 2h)$$

and thus $\frac{\partial EU_P(x_1, \mu = (\mu_1^L, 0, \tilde{\mu}, 0))}{\partial \tilde{\mu}} = \frac{\mu_1^L}{4} (1 - 2l) - \frac{\delta}{2} (h - l) + \frac{\delta}{2} (1 - \mu_1^L) (1 - h - l) - (2 - \mu_1^L) \frac{\delta}{4} (1 - 2h) > 0$ which can be shown to be true. Thus P prefers $\mu = (\mu_1^L, 0, 1, 0)$ over $\mu = (\mu_1^L, 0, \tilde{\mu}, 0)$. In addition, we know from above that P prefers $\mu = (1, 0, 1, 0)$ over $\mu = (\mu_1^L, 0, 1, 0)$.

- $A(\mu_1^L, 0, 1, 1) \subset A(1, 0, 1, 1)$ for all $\mu_1^L \in (0, 1)$.

For $x_1 \in A(\mu_1^L, 0, 1, 1) = \begin{cases} (l + \delta(h-l), h) & \text{if } \tau < \hat{\tau}^u, \\ (l + \frac{\delta}{2}(h-l), h) & \text{if } \tau > \hat{\tau}^u, \end{cases}$ P prefers the continuation equilibrium associated with $\mu = (1, 0, 1, 1)$:

(a) Suppose $\tau < \hat{\tau}^u$: $EU_P(\tilde{x}^1, \tilde{\mu}) = \frac{\tilde{\mu}}{2} (1 - l - \delta(h-l) - h) + \left(1 - \frac{\tilde{\mu}}{2}\right) \delta(1 - 2h)$ and $\frac{\partial EU_P(x_1, \tilde{\mu})}{\partial \tilde{\mu}} = \frac{1}{2} (1 - l - \delta(h-l) - h) - \frac{\delta}{2} (1 - 2h) > 0$ which is true because $1 - l - h > \delta(1 - h - l)$.

(b) Suppose $\tau > \hat{\tau}^u$: $EU_P(\tilde{x}^1, \tilde{\mu}) = \frac{\tilde{\mu}}{2} (1 - l - \frac{\delta}{2}(h-l) - h) + \left(1 - \frac{\tilde{\mu}}{2}\right) \frac{\delta}{2} (1 - h - l)$ and $\frac{\partial EU_P(x_1, \tilde{\mu})}{\partial \tilde{\mu}} = \frac{1}{2} (1 - l - \frac{\delta}{2}(h-l) - h) - \frac{\delta}{4} (1 - h - l) > 0$ which can be shown to be true. Thus, for $x_1 = A(\mu_1^L, 0, 1, 1)$, P prefers the continuation equilibrium associated with $\mu = (1, 0, 1, 1)$.

In addition, one can show that

- $A(\mu, 0, \mu, 0) \subset (A(\bar{\mu}, 0, \bar{\mu}, 0) \cup A(\bar{\mu}, 0, \hat{\mu}, 0) \cup A(\hat{\mu}, 0, \bar{\mu}, 0) \cup A(\bar{\mu}, 0, 1, 0) \cup A(1, 0, \bar{\mu}, 0) \cup A(1, 0, 1, 0))$ for all $\mu \in \left(\frac{\delta}{2-\delta}, \bar{\mu}\right)$ with $\hat{\mu} = \frac{2\bar{\mu}(x_1-l)-\delta\tau}{x_2-l+\bar{\mu}(x_1-l)-\delta\tau}$. For each of the cheapest points of $A(\mu, 0, \mu, 0)$, i.e., where $\tilde{x}_1 + \tilde{x}_2 = l + h + \delta(h-l)$, P prefers the continuation equilibrium associated with $\mu = (\bar{\mu}, 0, \bar{\mu}, 0)$: We have $EU_P(\tilde{x}^1, \mu = (\bar{\mu}, 0, \bar{\mu}, 0)) = \frac{\bar{\mu}^2}{4} (1 - h - l - \delta(h-l)) + 2\delta \frac{\bar{\mu}}{2} \left(1 - \frac{\bar{\mu}}{2}\right) (1 - h - l) + \left(1 - \frac{\bar{\mu}}{2}\right) \left(1 - \frac{\bar{\mu}}{2}\right) \delta \frac{1-\bar{\mu}}{2-\bar{\mu}} (1 - h - l)$ and thus $\frac{\partial EU_P(x_1, \bar{\mu})}{\partial \bar{\mu}} = \frac{\bar{\mu}}{2} (1 - h - l - \delta(h-l)) + (1 - 2\bar{\mu}) \frac{\delta}{4} (1 - h - l) > 0$ which can be shown

to hold true.

Consequently, we can solve multiplicity of equilibrium points (i.e., at a given point in Period 1 proposal space there are multiple voting Y probabilities leading to an equilibrium) by laying focus on the equilibrium that is associated with the largest probability of Period 1 passage. So the areas specified in Proposition 3 (and Figure 1.4) are the areas, together with the respective voting Y probabilities, that are not part of any other area associated with a larger voting Y probability (w.l.o.g. suppose that $\mu_1^L \leq \mu_2^L$ and define $\bar{\mu} = \frac{3h-l-1}{h-l} = 1 - \frac{1-2h}{h-l}$):

1. Region 1: Both responders vote N irrespective of their type, i.e. $\mu = (0, 0, 0, 0)$. The area that is not part of any of the other equilibrium areas.

2. Region 2: $A(0, 0, 1, 1) = \begin{cases} \text{conv} \{(0, h), (l + \frac{\delta}{2}\tau, h)\} & \tau > \hat{\tau}^u, \\ \text{conv} \{(0, h), (h, h)\} & \tau < \hat{\tau}^u \end{cases}$ (see Lemma 7), joint with its symmetric counterpart.

3. Region 3:

$$A(\bar{\mu}, 0, \bar{\mu}, 0) = \text{conv} \left\{ \left(l + \delta\tau, l + \frac{\delta}{\bar{\mu}}\tau \right), \left(l + 2\frac{\delta}{\bar{\mu}}\tau, l + 2\frac{\delta}{\bar{\mu}}\tau \right), \left(l + \frac{\delta}{\bar{\mu}}\tau, l + \delta\tau \right) \right\} \text{ if } \delta \in \left(0, \frac{\bar{\mu}}{2} \right),$$

$$A(\bar{\mu}, 0, \bar{\mu}, 0) = \text{conv} \left\{ \left(l + \delta\tau, l + \frac{\delta}{\bar{\mu}}\tau \right), \left(h - \frac{(2\delta - \bar{\mu})(1 - \bar{\mu})}{\bar{\mu}}\tau, h \right), (h, h), \right. \\ \left. \left(h, h - \frac{(2\delta - \bar{\mu})(1 - \bar{\mu})}{\bar{\mu}}\tau \right), \left(l + \frac{\delta}{\bar{\mu}}\tau, l + \delta\tau \right) \right\}$$

if $\delta \in \left(\frac{\bar{\mu}}{2}, \bar{\mu} \right)$,

and $A(\bar{\mu}, 0, \bar{\mu}, 0) = \text{conv} \left\{ \left(l + \left(\delta \frac{1+\bar{\mu}}{\bar{\mu}} - 1 \right) \tau, h \right), (h, h), \left(h, l + \left(\delta \frac{1+\bar{\mu}}{\bar{\mu}} - 1 \right) \tau \right) \right\}$ if $\delta \in \left(\bar{\mu}, \frac{2\bar{\mu}}{1+\bar{\mu}} \right)$ (allocating in total more than $2l + \frac{1+\bar{\mu}}{\bar{\mu}}\delta\tau$).

4. Region 4:

$$A(\bar{\mu}, 0, \hat{\mu}, 0) = \begin{pmatrix} \text{conv} \left\{ \left(l + \delta\tau, l + \frac{\delta}{\bar{\mu}}\tau \right), \left(l + \frac{2}{\bar{\mu}}\delta\tau, l + \frac{2}{\bar{\mu}}\delta\tau \right), \left(l + 2\delta\tau, l + \frac{2}{\bar{\mu}}\delta\tau \right) \right\} & \text{if } \delta \in (0, \frac{\bar{\mu}}{2}), \\ \text{conv} \left\{ \left(l + \delta\tau, l + \frac{\delta}{\bar{\mu}}\tau \right), \left(l + \left(\frac{(\bar{\mu}-\delta)(2-\bar{\mu})}{\bar{\mu}} + \delta \right) \tau, h \right), (l + \bar{\mu}\tau, h) \right\} & \text{if } \delta \in (\frac{\bar{\mu}}{2}, \bar{\mu}) \end{pmatrix}$$

(where $\hat{\mu} = \frac{2\bar{\mu}(x_1-l)-\delta\tau}{x_2-l+\bar{\mu}(x_1-l)-\delta\tau}$), joint with its symmetric counterpart.

5. Region 5:

$$A(\bar{\mu}, 0, 1, 0) = \text{conv} \left\{ \left(l + \delta\tau, l + \frac{\delta}{\bar{\mu}}\tau \right), (l + \delta\tau, h), (\min \{l + 2\delta\tau, l + \bar{\mu}\tau\}, h), \right. \\ \left. \left(\min \{l + 2\delta\tau, l + \bar{\mu}\tau\}, \min \left\{ l + 2\frac{\delta}{\bar{\mu}}\tau, h \right\} \right) \right\}$$

(given $\delta < \bar{\mu}$), joint with its symmetric counterpart.

6. Region 6: $A(1, 0, 1, 0) = \text{conv} \{(l + 2\delta\tau, l + 2\delta\tau), (l + 2\delta\tau, h), (h, h), (h, l + 2\delta\tau)\}$ (given $\delta < \frac{1}{2}$).

7. Region 7: $A(1, 0, 1, 1) = \begin{cases} \text{conv} \{(l + \frac{\delta}{2}(h-l), h), (h, h)\} & \tau > \hat{\tau}^u, \\ \text{conv} \{(l + \delta(h-l), h), (h, h)\} & \tau < \hat{\tau}^u, \end{cases}$ joint with its symmetric counterpart.

8. Region 8: $\mu = (1, 1, 1, 1)$ and allocating at least h to each responder.

Chapter 2

Legislative bargaining with private information: Experimental results on the comparison of different voting rules¹

Abstract

This paper experimentally investigates behavior in a legislative bargaining game with private information. A single proposer is seeking to pass a proposal. In each of two rounds, she attempts to buy the necessary votes by offering payments. Between rounds, the game ends in breakdown with a certain probability. The two responders hold privately known disagreement values. We compare behavior under majority (one vote needed) vs. unanimity (both votes needed) rule. The main theoretical prediction is that responders are more “expensive” in round 1 under unanimity rule because there exists a signaling incentive to vote “no”. Under majority rule, this incentive is absent and in fact responders should fear being excluded after voting “no”. Our experimental findings confirm the presence of signaling incentives under unanimity rule, resulting in lower agreement probabilities than under majority rule. In contrast, the experimental evidence under majority rule is mixed and does not fully coincide with the theoretical predictions.

JEL codes: C78; C92; D72; D82; D91

Keywords: bargaining; experiment; majority; unanimity; private information

¹This paper is jointly written with Christoph Vanberg.

2.1 Introduction

“The demand to extend qualified majority voting is a constant topic in the debate on the EU’s ability to act. [...] All too often, EU decisions are blocked by individual vetoes with which national governments want to push through particular interests, demand material compensation, or even hope to obtain concessions on other matters that are not directly at issue.” (Mintel and Ondarza (2022), German Institute for International and Security Affairs)

Multilateral negotiations are ubiquitous in both political and economic organizations. Depending on the contexts, groups use different rules to bargain and establish binding agreements for their members. Especially in the political context, these rules often involve explicit voting on proposals according to either a qualified majority rule or, in especially sensitive areas, unanimity rule. An important feature in many such negotiations is that group members possess private information as to their own preferences regarding a proposed change to the status quo. This paper aims to experimentally investigate how such privately held information affects bargaining behavior under alternative voting rules.

The intuition motivating the investigation is that unanimity rule creates incentives for individuals to understate the value they attach to a reform - or to overstate the harm they expect to suffer - in an effort to secure concessions from others. Majority rule, in contrast, may induce participants to agree even to proposals that they are opposed to, for fear of being excluded from a winning coalition. In a companion paper (Piazolo and Vanberg (2024a)), we analyze a formal model of this intuition. The aim of this paper is to investigate some of its main predictions in a laboratory setting.

Specifically, we conduct a laboratory experiment in which subjects negotiate over the allocation of a pie between a proposer and two responders. Responders are endowed with privately known “breakdown value” - a payoff they receive if the group fails to reach agreement. This payoff can be interpreted as the value attached to the status quo. Negotiations run for at most two periods and there is a chance of immediate breakdown following Pe-

riod 1. We vary the voting rule (unanimity versus majority), the information regarding breakdown values (private versus public), and the probability of breakdown (low versus high).

The theoretical predictions for the private information conditions are based on the equilibrium analysis presented in our companion paper, Piazzolo and Vanberg (2024a). The primary result of that analysis is that private information about breakdown values (i.e., a preference for not reaching an agreement) increases a responder’s incentive to vote No under unanimity voting, while it encourages a Yes vote under majority voting. The reason is that voting “No” (“Yes”) on certain proposals in Period 1 constitutes a signal that a responder’s breakdown value is high (low). The incentives to send these signals differ between the voting rules. Under unanimity rule, it is beneficial to be perceived as a high breakdown value type, as this may prompt better offers. Under majority rule, it is disadvantageous, as the proposer can exclude “expensive” responders from future coalitions. These considerations are important (only) if the likelihood of reaching Period 2 is large enough. Thus, the main qualitative prediction from the equilibrium analysis is that responders are more “expensive” under unanimity rule with private information and a high continuation probability, as compared to situations where one or more of these factors are absent. A second hypothesis is that responders should vote “Yes” under majority rule and a high continuation probability, even when they are offered “peanuts”.

Our main results are the following. Under unanimity rule, behavior is largely consistent with the equilibrium predictions. Rejection rates increase with δ and are higher when breakdown values are privately known. This is consistent with the idea that subjects want to be perceived as having a high breakdown value and understand that voting “No” can help to signal that. In contrast, behavior under majority rule diverges significantly from equilibrium predictions. Across both information regimes and regardless of δ , most responders consistently vote “No” on offers below their breakdown value - offers which a selfish payoff maximizer should accept if they anticipate being excluded in Period 2. As

a consequence, the differences in voting behavior under the two rules are less pronounced than predicted.

One way to summarize these findings is that responders behave under majority rule as if they are using unanimity rule. A plausible interpretation is that subjects do not anticipate being excluded from a future coalition if they vote “N”. Indeed, we find that proposers do not consistently form minimum winning coalitions as theoretically predicted, and even when they do, Period 2 proposals often do not exclude responders who voted “N” in Period 1. Another (complementary) interpretation of our results is that subjects may be motivated by fairness concerns. In an ex-post theoretical exercise, we show that the introduction of such concerns into our model affects predictions under majority rule more dramatically than under unanimity rule, leading to smaller differences in predicted behavior, consistent with our findings.

The remainder of the paper is structured as follows. Section 2.2 briefly discusses related literature. Section 2.3 describes the model and outlines the theoretical predictions. Section 2.4 describes the experimental design and states our experimental hypotheses. Results are presented in Section 2.5. Section 2.6 presents the ex-post theoretical analysis. Finally, Section 2.7 concludes. Additional results and analyses are presented in the Appendix.

2.2 Literature

The theoretical framework used in this paper is based on the classic multilateral bargaining model of Baron and Ferejohn (1989). This model considers a purely distributive bargaining problem. Players negotiate over how to split a pie of size one, requiring a simple majority vote for an agreement. A large body of literature has since developed around these “divide a dollar” games (Eraslan and Evdokimov (2019)). Of particular relevance to our analysis is the model of Miller et al. (2018) who present a modified version of the game, assuming that negotiations can break down and that players receive heterogeneous (and publicly known) “breakdown values” in this case. Breakdown values can be interpreted as payoffs

associated with the status quo that prevails if agreement on a reform fails. Virtually all theoretical work in this area assumes that the players' preferences are common knowledge.

In contrast, theoretical literature on multilateral bargaining with private information remains limited. Tsai and Yang (2010b) examine a three-player, three-period Baron-Ferejohn game with private information about discount factors. They show that under majority rule, equilibrium may involve delays and oversized coalitions. In Piazzolo and Vanberg (2024a), we investigate a two period version of Miller et al. (2018) with privately known breakdown values. This model and its main predictions are described in more detail in Section 2.3.

This paper contributes to the experimental literature on multilateral bargaining. In their meta-analysis, Baranski and Morton (2022) review the results from all experiments on the majoritarian Baron-Ferejohn bargaining game conducted prior to 2019. Their analysis uncovers a notable discrepancy between theoretical predictions and experimental findings, particularly highlighting the influence of other-regarding preferences and negative reciprocity. While Minimum Winning Coalitions (MWC) are proposed most frequently, they occur less often than theory predicts, while equal splits are common. Agranov et al. (2022) present a similar finding. They conduct a multilateral bargaining experiment with stochastic uncertainty about the pie size in subsequent rounds. One of their findings is that the threat of being excluded under majority voting plays a smaller role than theory predicts, resulting in lower proposer power.

In the absence of private information, Agranov and Tergiman (2014) explore the influence of communication in bargaining under majority rule. Their findings show that enabling subjects to engage in unrestricted cheap-talk increases proposer power. It reduces uncertainty about participants' willingness to accept offers and heightens competition to be included in the winning coalition. Under unanimity rule, Agranov and Tergiman (2019) find that communication has opposing effects. It shifts bargaining outcomes toward more egalitarian allocations and thereby diminishes proposer power. Our experiment also features communication, albeit more limited. We find that when subjects send messages along

with a vote to reject a proposal, this increases the likelihood that they will be included in a subsequent coalition.

Bilateral bargaining with private information was the subject of extensive experimental investigation in the past. This literature is summarized in Kennan and Wilson (1993) and Roth et al. (1995), among others. Much of this research focuses on ultimatum games where proposers are privately informed about the pie size (see, for instance, Mitzkewitz and Nagel (1993), Kagel et al. (1996), or Croson (1996)). In this context, Croson et al. (2003) experimentally observes that bargaining outcomes are influenced by false claims about private information and threats of future actions. Additionally, both Güth et al. (1996) and Rapoport and Sundali (1996) find that many proposers pretend to propose an equal split by acting as if the pie was smaller than it actually is. Similar patterns have been observed in “unstructured” bargaining situations (see Camerer et al. (2019)). To the best of our knowledge, this is the first multilateral bargaining experiment involving private information.

2.3 Theory

This section begins by describing the model on which the experimental design is based. We briefly outline the main theoretical predictions in general terms. Then we will introduce the specific parameter constellations used in the experiment and formulate experimental hypotheses given those parameters. Throughout, we will keep theoretical details to a minimum. A more thorough analysis of the private information version of the model can be found in Piazzolo and Vanberg (2024a).

Model and equilibrium concept The game involves three players, one proposer (P, she) and two responders (R1 and R2, he). The group bargains over the distribution of a pie worth 100 “tokens”. In each of at most two rounds $t \in \{1, 2\}$, P makes a proposal $x^t = (x_1^t, x_2^t)$, where x_i^t is the amount being offered to responder i . Responders then vote

simultaneously either “Yes” (Y) or “No” (N). If at least q responders vote Y, the proposal passes. In this case, the game ends, responders obtain their shares x_i^t and P receives the remainder $100 - x_1^t - x_2^t$. Otherwise, the proposal fails.

If the proposal fails in Period 1, the game ends in “breakdown” with probability $1 - \delta$. With probability δ , a second round of bargaining ensues. If there is no agreement in round 2, the game ends in breakdown with probability 1. In case of a breakdown, P receives 0 tokens and each responder i receives his “breakdown value” $b_i \in \{l, h\}$ with $0 < l < h < 50$. These breakdown values are equally likely ex ante. We refer to a responder with a low (high) breakdown value as a *low (high) type*.

Our equilibrium concept is Subgame Perfect / Perfect Bayesian Equilibrium in stage-wise undominated strategies. The elimination of dominated strategies rules out intuitively unreasonable equilibria where responders vote in a way that is opposite to their interest when their vote is not pivotal.

2.3.1 Equilibrium under public information

We begin by assuming that all players are informed about both of the responders’ breakdown values.

Unanimity rule

Suppose the voting rule is unanimity. If Period 2 is reached, responders will vote Y iff they are offered at least their breakdown value. It is then easy to conclude that the same applies in Period 1. Therefore the equilibrium prediction for unanimity rule and public information is that responders vote Y iff they are offered their breakdown value. Given this, P secures immediate agreement by making the appropriate proposal.

Majority rule

Under majority rule, the logic is quite different. In Period 2, voters will again vote Y iff they are offered their breakdown value. However, P now needs only one vote, therefore she would form a Minimum Winning Coalition (MWC). If the responders' breakdown values differ, P will include the "cheaper" (low breakdown value) responder in Period 2. If breakdown values are the same, P can include either one - and exclude the other. A responder who expects to be excluded in Period 2 is willing to vote Y on a Period 1 proposal that includes him in a MWC iff he is offered at least $(1 - \delta)b_i$. That is, he is willing to accept less than his breakdown value. This enhanced willingness to accept is driven by what we will call his "fear of exclusion" - a fear that is absent under unanimity rule, and that becomes more relevant under majority rule the larger is δ .

When responders have the same breakdown value, P can credibly threaten to exclude either one in Period 2, thus inducing a "price" of $(1 - \delta)b_i$ for his vote. If breakdown values differ, P must include the low type in Period 2. Therefore the threat of exclusion is credible only if it is directed at the high type, inducing a price of $(1 - \delta)h$ for the high, and l for the low type. Which responder P prefers to include in this case depends on δ . These arguments establish the following equilibrium predictions for the public information version of the game.

The first prediction describes the responders' voting behavior in Period 1 under public information for both of the voting rules.

Equilibrium Prediction 1. *[Period 1 voting under public information]*

- (a) *Unanimity rule: Responders vote Y iff offered at least their breakdown value.*
- (b) *Majority rule: Responders included in a MWC vote Y iff offered at least $(1 - \delta)$ times their breakdown value. (Exception: When responder types differ, the low type's price is l .)*

The next describes the proposer's behavior.

Equilibrium Prediction 2. *[Period 1 proposals under public information]*

- (a) *Unanimity rule:* P offers both responders their breakdown value and they vote Y .
- (b) *Majority rule:*
 - If types differ and δ is small: P offers l to the low type and he votes Y .
 - If types differ and δ is large: P offers $(1 - \delta)h$ to the high type and he votes Y .
 - If types are the same: P offers $(1 - \delta)b_i$ to either responder and he votes Y .

2.3.2 Equilibrium under private information

Next, consider the case where responders are privately informed about their breakdown value and both types are equally likely ex ante.

Unanimity rule

As in the public information setup, high-type responders vote Y only if they are offered at least their breakdown value h . However, for low-type responders, the decision is more nuanced. Voting Y on an offer below h reveals their type, a costly signal if negotiations proceed to Period 2. In this second period, P will tailor her proposal based on her updated beliefs about the responders' types, offering l to those that have signalled that they are of the low type. By the same logic, voting N on a Period 1 proposal signals that the respective responder is likely to be a high type, (potentially) convincing P to offer him h in Period 2.

Both the *negative signaling value from voting Y* and the *positive signaling value from voting N* reduce a low type's willingness to vote Y in Period 1, effectively raising his "price" above his breakdown value. The importance of these signaling incentives grows as the likelihood of reaching Period 2 increases. Therefore, the low-type responder's price is increasing in the continuation probability δ . In addition, this price is influenced by what the *other* responder is being offered. If a responder is confident that the other responder will vote Y , he need not worry about the negative signaling value of voting Y , as doing so would lead to immediate agreement. Conversely, if he expects the other responder to vote

N, he will refuse any offer below h , as voting Y will not lead to agreement but the negative signaling value remains. In sum, the low-type responder's equilibrium "price" increases with δ and decreases with the probability that the other responder votes Y.

If she is going to purchase a responder's vote at a price below h , P will have to compensate low-type responders for the signaling costs they incur by voting Y. To minimize the necessary premium, she can offer one responder h in order to secure his vote with certainty. This eliminates the *negative signaling value from voting Y* for the other responder, thereby reducing his price. Depending on the specific parameter values, this second responder will then be offered either the high type's or the low type's price. In the former case, the game will conclude in Period 1 with an agreement. In the latter case, the responder votes N if he is of the high type, potentially leading to a second-period negotiation, where he will then receive the high type's breakdown value.

Majority rule

We have seen in the public information context that the fear of being excluded from a Period 2 coalition makes even high-type responders relatively cheap to buy in Period 1, particularly when the continuation probability δ is high. When breakdown values are private information, this threat is further amplified as Voting N in Period 1 may signal that a responder has a large breakdown value, making him less attractive as a coalition partner in Period 2.

Voting N thus carries a *negative signaling value* under majority rule. It turns out that this effect is most pronounced when P builds a MWC in Period 1. Since the excluded responder is then sure to vote N, she learns nothing about his type in the event of proposal failure. Therefore, if the included responder also votes N, P will switch coalition partners in Period 2. Thus, the threat of exclusion is perfect and the included responder is as cheap as he can possibly be (with a price of $(1 - \delta)b_i$). Again, the threat of exclusion is increasing (and thus the "price" is decreasing) in δ . If P instead includes both responders

in her Period 1 proposal, the threat of exclusion is mitigated since she cannot exclude both in Period 2.² As a result of these principles, P will propose a MWC in Period 1 unless the difference in breakdown values is very large.³ These considerations yield the following equilibrium predictions for the private information version of the game.

Again, the first prediction describes the responders' voting behavior.

Equilibrium Prediction 3. *[Period 1 voting under private information]*

- (a) *Unanimity rule: High types vote Y iff offered at least h . Low types vote Y iff they are offered at least their "price" z_l^u with the following properties:*
- $z_l^u > l$,
 - z_l^u is increasing in δ , and
 - z_l^u is decreasing in the probability that the other responder votes Y.
- (b) *Majority rule: Both high and low type "prices" have the following properties:*
- $z_l^m < l$ (when facing a MWC) and $z_h^m < h$ (always),
 - z_l^m and z_h^m are decreasing in δ (when facing a MWC), and
 - z_l^m and z_h^m are lower if the other responder votes N for sure than if he might vote Y.

The second prediction describes the proposer's behavior.

Equilibrium Prediction 4. *[Period 1 proposals under private information]*

- (a) *Unanimity rule:*
- *If the difference between breakdown values is small: P offers h to both responders and they each vote Y for sure.*
 - *Otherwise: P offers one responder h and z_l^u to the other such that he votes Y iff his type is low. (If the proposal fails, the proposer in Period 2 offers h to the responder with the smaller Period 1 offer and l to the other.)*

²In this case, it turns out that a given responder's price is increasing in the probability with which the other responder votes Y. That is, making a more attractive offer to one responder makes the other more expensive to buy.

³If the difference in breakdown values is very large, P will offer both responders the low type's price. If both vote N, P will then offer h to one of them in Period 2.

(b) *Majority rule:*

- *If the difference between breakdown values is small and δ is large: P offers $(1 - \delta)h$ to one responder and he votes Y for sure.*
- *Otherwise: P offers z_l^m to both and they each vote Y iff their type is low. (If the proposal fails, P will offer one of them h in Period 2, and zero to the other.)*

2.4 Experiment

In the experiment, parameters are set as follows. The breakdown values are $l = 10$ and $h = 45$ tokens. We vary the continuation probability between $\delta = 1/6$ and $\delta = 5/6$. This treatment is applied between subjects, as is the decision rule (majority, unanimity).

2.4.1 Hypotheses

In what follows, we present specific experimental hypotheses reflecting equilibrium predictions for the given parameter values. One set of hypotheses concerns responders' voting behavior, while others pertain to the proposals actually made by P , the likelihood of reaching an agreement, and the messages responders are permitted to send. We begin by introducing hypotheses specific to each voting rule, followed by those that compare behavioral patterns across the two voting rules.

Unanimity rule

Under unanimity rule, a responder expects to be pivotal if his counterpart receives an offer above the high type's breakdown value (45 tokens). Our equilibrium analysis yields predictions as to the "price" that responders must be offered in exchange for their Yes-vote under this condition.

According to Equilibrium Predictions 1 and 3, a high type's price is 45 tokens under both public and private information. For low types, the price depends on the information regime and the continuation probability. Under public information, it is 10 tokens. Under

private information, it increases to approximately 13 tokens when $\delta = \frac{1}{6}$ and 25 tokens when $\delta = \frac{5}{6}$. (Table 2.11 in the Appendix summarizes responder prices more precisely). These differences reflect the *positive signaling value from voting N* and its dependence on the continuation probability. A prediction emerging from our equilibrium analysis is that whenever a proposal allocates at least 45 tokens to the “other” responder, subjects with a low breakdown value will vote N if offered less than these prices and Y if offered more.

To test this prediction, our experiment features responders voting on proposals that we exogenously introduce into the game. (See the experimental design section for details as to this procedure.) Table 2.1 summarizes how a low-type responder is expected to vote on these proposals, according to the equilibrium analysis. High-type responders are predicted to vote N on all such proposals. (See Tables 2.13 and 2.14 for a complete overview of the exogenous proposals and the corresponding voting predictions.)

Table 2.1: Voting predictions when pivotal (unanimity rule, low type)

proposal	Public Info		Private Info	
	$\delta = 1/6$	$\delta = 5/6$	$\delta = 1/6$	$\delta = 5/6$
(30,46)	Y	Y	Y	Y
(20,46)	Y	Y	Y	N
(10,46)	Y	Y	N	N

As discussed above, the pivotal responder’s price under private information increases with δ . This pattern is reflected here in the prediction that the responder votes Y on (20, 46) when $\delta = 1/6$ and N when $\delta = 5/6$ (see Table 2.1). Similarly, a low type’s price is expected to rise when moving from public information to private information regarding breakdown values. This is again reflected in a responder voting Y on (20, 46) when $\delta = 5/6$ in the public information case but voting N in the private information case. These two predictions lead to the following hypothesis:

Hypothesis U1. *Under unanimity rule, responders are less likely to vote Yes on the Period 1 proposal under private information and when the continuation probability is high. In particular:*

- (a) *under private information, pivotal low types more often vote Yes on the exogenous proposal (20, 46) when $\delta = 1/6$ than when $\delta = 5/6$.*
- (b) *When $\delta = 5/6$, pivotal low types more often vote Yes on the exogenous proposal (20, 46) under public information than under private information.*

In addition to proposals designed to make one responder pivotal, we included two proposals that treat responders equally: the three way equal split ((33, 33)) and another where P attempts to keep a larger share ((20, 20)). Under private information and when $\delta = 5/6$, the equilibrium prediction is for low type responders to vote N on the equal split - despite the fact that they should vote Y on (30, 46) (see Tables 2.14 and 2.1), reflecting the fact that their equilibrium price is higher when the other responder is offered less than h .⁴ This brings us to the following hypothesis:

Hypothesis U2. *Under unanimity rule, private information, and $\delta = 5/6$, low types vote Yes more often on the proposal (30, 46) than on the proposal (33, 33).*

Note that Hypothesis U1 is based on the *positive signaling value from voting N*, while Hypothesis U2 relies on the *negative signaling value from voting Y*. Both are based on responders anticipation of P's behavior in Period 2. Specifically, P is predicted to offer the high share to responders who have signaled that they are likely high types (by voting N). Conversely, she should offer the low share to responders who have signaled that they are low types (by voting Y on offers below 45). This yields the next hypothesis:

Hypothesis U3. *Under unanimity rule and private information, P is more likely to offer the high share in Period 2 to responders that have voted No in Period 1 compared to responders that have voted Yes.*

⁴The reasoning is as follows: When the other responder (say, R2) is offered less than 45, he will vote N if he is a high type. In this case R1's vote is not pivotal and voting Y is associated with *negative signaling value*.

Majority rule

Under majority rule, responders are pivotal when they are included in a MWC, i.e., when the “other” responder is offered zero. Their prices then simply amount to $(1 - \delta)b_i$ under both information regimes.⁵ (An exception occurs when breakdown values are publicly known and differ between responders. Then the low type is not worried about exclusion and so his price is simply $l = 10$. Table 2.12 summarizes these prices.) These predictions reflect the main qualitative patterns identified in Equilibrium Predictions 1 and 3: When δ is small, responders included in a MWC are willing to accept only slightly less than their breakdown values, as the *fear of exclusion* does not weigh heavily when breakdown is likely. When δ is large, however, that fear becomes more relevant and they are willing to accept “peanuts”. Since the fear of exclusion is present under both information regimes, the predicted differences between public and private information are smaller than for unanimity rule.

As under unanimity rule, we test these predictions by exogenously introducing a set of MWC proposals into the game. Table 2.2 summarizes these proposals as well as how high-type responders are predicted to vote on them. Low-type responders are predicted to vote Y on all of these proposals (see Table 2.13).

Table 2.2: Voting predictions when pivotal (majority rule, high type)

proposal	Public Info		Private Info	
	$\delta = 1/6$	$\delta = 5/6$	$\delta = 1/6$	$\delta = 5/6$
(30,0)	N	Y	N	Y
(20,0)	N	Y	N	Y
(10,0)	N	Y	N	Y

This reasoning leads us to the following Hypothesis regarding high type voting behavior under majority rule. (Note that this hypothesis applies to both public and private

⁵In each case, the equilibrium prediction for Period 1 proposals is that P forms a MWC with the cheaper partner. For example, when types differ, breakdown values are publicly observable, and $\delta = 5/6$, she offers 7.5 to the high-type responder and he votes Y. The high type is, in this case, the cheaper partner because he must fear exclusion in Period 2.

information.)

Hypothesis M1. *Under majority rule, pivotal high types included in a MWC more often vote Yes on offers less than 45 tokens when $\delta = 5/6$ than when $\delta = 1/6$. This difference arises under public and private information.*

Like the hypotheses regarding voting behavior under unanimity rule, the mechanism underlying these hypotheses involve responders anticipating proposer behavior in Period 2. Specifically, responders included in a MWC should expect that if they vote N and Period 2 is reached, P will *exclude* them and form a MWC with the other responder. This “fear of exclusion” is theoretically relevant under both information regimes. Under private information, it is supported by the fact that voting N could be interpreted as a signal that the responder is a high type.⁶

Hypothesis M2. *Under majority rule, proposers will exclude a responder in Period 2 if they vote N on a MWC proposal that included them in Period 1.*

Unanimity vs. majority rule

Recall that under majority rule, pivotal responders may vote Y on offers below their breakdown value, while under unanimity rule, they may vote N on offers above their breakdown value (see Tables 2.1 and 2.2). The primary drivers of these differences are the *threat of exclusion* under majority voting and the *positive signaling value from voting N* under unanimity voting. Both factors become particularly relevant when the continuation probability is high and breakdown values are privately known. From this, Hypothesis UM1 follows.⁷

Hypothesis UM1. *Under private information and high continuation probability, pivotal responders are more likely to vote Yes when offered 20 under majority rule than under unanimity rule.*

⁶Under public information, an exception to this rule occurs when responder breakdown values differ. In this case, P must include the low type in Period 2, even if they have rejected the Period 1 proposal. We neglect this exception in our stated Hypothesis for simplicity.

⁷As shown in Table 2.14, the pattern described in Hypothesis UM1 also applies to proposals where the responder’s vote may not be pivotal (for instance, the equal proposal).

Combining this hypothesis with the fact that unanimity rule requires more Yes-votes for an agreement than majority rule directly leads to the next hypothesis. Under unanimity rule, not only are more responders needed to reach an agreement, but each responder is also more “expensive” compared to majority voting. As a result, agreements become more difficult and less likely to be achieved:

Hypothesis UM2. *The frequency of Period 1 agreement is lower under unanimity rule than under majority rule. The difference is most pronounced under private information and $\delta = 5/6$.*

In addition to simply voting Y or N, our experimental interface allowed responders to include a message with their vote which would be visible to all group members. This feature was introduced because we expected it to support the effectiveness of signals by allowing responders to explicitly explain how P should interpret their vote choice. In addition, these messages offer potential insights into whether responders intend for P to perceive them as high types or not. This allows us to directly test the conjecture that responders wish to be perceived as high types under unanimity rule but not under majority rule, motivating the following hypothesis.

Hypothesis UM3. *Under private information, messages indicating that a responder has a high breakdown value are sent more often under unanimity than under majority rule.*

2.4.2 Experimental design

We now turn to describing details of our experimental implementation. Recall that the experiment featured variation in the following treatment parameters:

- Decision rule: Majority vs. Unanimity
- Continuation probability: High ($\delta = 5/6$) vs. Low ($\delta = 1/6$)
- Information regime: Public vs. Private

2. Multilateral bargaining with private information: Experiment

The decision rule and continuation probability were varied *between* subjects in a 2x2 design, as summarized in the following table. Each combination was conducted with six matching groups consisting of 9 subjects,⁸ for a total of 216 subjects participating in the experiment.⁹

Table 2.3: Between subject treatment parameters

Decision rule	Continuation probability	
	$\delta = 1/6$	$\delta = 5/6$
Majority	6 matching groups	6 matching groups
Unanimity	6 matching groups	6 matching groups

The information regime was varied *within* subjects. Specifically, each session was divided into two parts, each comprising 10 independent games. In one part, both responders' breakdown values were visible on all subjects' screens (see Figure 2.4) throughout the game, thus implementing the public information version of the game. In the other 10 rounds, only the responders' own breakdown values were displayed on their own screens, corresponding to the private information version of the game.¹⁰ The order of the private vs. public information parts was counterbalanced.

At the beginning of each game, subjects were randomly assigned to a groups, and proposer / responder roles and breakdown values were assigned.¹¹ Next, subjects were informed about their role and either their own or all players' breakdown values, depending on the information regime. This information remained visible on the screen throughout

⁸In each matching group (24), there is one proposal and four voting decisions for each group of three (3) in each of the rounds (20). In total, we thus observe 1440 Period 1 proposals and 5760 Period 1 voting decisions.

⁹Whenever the number of participants permitted, a given experimental session involved two matching groups that were assigned the same value for δ but different values for the decision rule. This was done to further improve the random assignment of subjects to decision rules.

¹⁰The screens in the two versions of the game differed only in that under private information, other subjects' breakdown values are displayed as question marks.

¹¹Matching and role assignment in all sessions followed a fixed scheme that was randomly predetermined to satisfy the following additional desiderata: (1) No two subjects meet in two consecutive rounds or more than four times per part (10 rounds), (2) each subject is proposer either 2 or 3 times per part, and (3) no subject faces the same proposer more than once per part. For simplicity, subjects were only told that they would be randomly rematched after each round.

the subsequent steps.

The proposer then makes a proposal on how to split the 100 tokens between herself and the two responders. Following this, responders are asked to vote sequentially on *two* proposals, one of which was made by the proposer, and the other being one of the “exogenous” proposals introduced above (see Table 2.13 and 2.14). Each exogenous proposal is presented twice to all subjects in a given matching group in each part of the experiment. The order in which the exogenous and endogenous proposals are presented is randomized such that responders do not know which proposal originates from P. After responders have voted (either Y or N) on both proposals, one proposal is randomly selected to be counted. That is, the exogenous proposal has a 1/2 chance of “overriding” the proposal that was made by the subject in the proposer role, thus ensuring that subjects take each proposal seriously, irrespective of whether they believe that it came from another subject or not.

In addition to casting a vote on each proposal, responders had the option of including a message that would be displayed to all group members along with that vote. We included this option in order to reinforce the signaling aspect of the vote, anticipating that subjects would send messages of the form “I am voting N because I have a high breakdown value”. Messages were constrained to be at most 90 characters in length.

All group members observe the respective voting decisions and possible messages for the decisive proposal. There is an immediate agreement if a sufficient number of responders has voted Y on the decisive proposal (one under majority rule, two under unanimity rule). Otherwise, a die roll determines whether there is a breakdown or a second period of bargaining (with probability $\delta \in \{\frac{1}{6}, \frac{5}{6}\}$). In a second period, P proposes a new split and responders vote on the revised proposal. (I.e., there were no exogenous proposals in Period 2.)

At the end of each experimental round, subjects received feedback on the outcome of the game and the tokens they will earn if that round is chosen for payment. At the end of the experiment, three rounds are randomly selected as payoff-relevant. Subjects receive

the total sum of tokens earned in these three rounds, along with a show-up fee of 5€. Each token is worth 0.1€. Payments varied between 5 and 39€, with a median of 23€. Sessions typically lasted between 60 and 90 minutes. The experiment was programmed using otree (Chen et al. (2016)). All sessions were conducted at the University of Heidelberg and the University of Mannheim in 2022.

2.5 Results

This section presents our results, beginning with voting on the exogenous proposals. Following this, we look at proposer behavior and responders' voting on endogenous proposals. Additionally, we analyze the probability of reaching an agreement and the occurrence and contents of the messages.

2.5.1 Unanimity rule

Table 2.4 presents the shares of *pivotal* responders that vote Y on the exogenous proposals under unanimity rule.¹² For further details about low-type Period 1 voting behavior, see Figures 2.12, 2.13 (public information) and Figure 2.9 (private information). The letters in parentheses indicate the equilibrium predictions.

Table 2.4: Share of pivotal responders voting Yes (unanimity rule, low type)

proposal	Public Info		Private Info	
	$\delta = 1/6$	$\delta = 5/6$	$\delta = 1/6$	$\delta = 5/6$
(30,46)	100% (Y)	77% (Y)	97% (Y)	57% (Y)
(20,46)	92% (Y)	71% (Y)	83% (Y)	27% (N)
(10,46)	22% (Y)	11% (Y)	25% (N)	13% (N)

Note: Y (N) indicates the voting behavior according to our equilibrium predictions.

These numbers are qualitatively consistent with our theoretical predictions. In partic-

¹²Each exogenous proposal is presented twice (2) within a given matching group for a given information regime (6), and yields one voting decision relevant to the Hypotheses - by the subject who is being offered 10, 20, or 30 - per game (3 games are played at a given time). Thus we observe $2 \cdot 6 \cdot 3 = 36$ relevant voting decisions on each of these proposals per treatment condition.

ular, the share of Yes-votes is larger for small delta than for large delta. This is confirmed by a Wilcoxon rank-sum test (see Table 2.18):¹³ Specifically, for the proposal (20, 46), the difference between the two groups (low vs. high delta) is highly significant ($p < 0.01$) in the private information setup. Likewise, when delta is large, the (20, 46) proposal receives more Yes-votes in the public information setting than in the private one ($p < 0.05$, see Table 2.20).¹⁴ This leads us to the following result:

Result U1. *Under unanimity rule, responders are less likely to vote Yes on the Period 1 proposal under private information and when the continuation probability is high. In particular:*

- (a) *Under private information, the share of pivotal low types voting Yes on (20, 46) is larger when $\delta = 1/6$ than when $\delta = 5/6$.*
- (b) *When $\delta = 5/6$, the share of pivotal low types voting Yes on (20, 46) is larger under public information than under private information.*

Result U1 supports Hypothesis U1 and aligns with the idea that responders take into account the *positive signaling value from voting N*.

However, the *negative signaling value from voting Y* does not seem to be considered in the way we predicted. Under private information and $\delta = 5/6$, a larger share of low-type responders votes Y when faced with the equal proposal (70%, see Table 2.17) than when faced with the (30, 46) proposal, where they are pivotal (57%, see Table 2.4). This contradicts Hypothesis U2.

Result U2. *Under unanimity rule, private information, and $\delta = 5/6$, low types do not vote Yes more often on the proposal (30, 46) than on the proposal (33, 33).*

¹³The Wilcoxon rank-sum test compares the average share of Yes-votes per matching group. As a robustness check, a two-proportion z-test, which compares the binary outcome (Yes or No) at the individual level, also confirms our results (see Table 2.19).

¹⁴Generalized Estimating Equations (Hardin and Hilbe (2002)) also confirm this significant difference (see Table 2.21). We use the Wilcoxon rank-sum test (and two-proportion z-test) to compare proportions (of a binary outcome) between independent groups, such as $\delta = 1/6$ and $\delta = 5/6$, since delta remains fixed for each subject throughout the experiment. For binary outcomes involving matched data, such as public vs. private information setups, where subjects encounter both, we use the Wilcoxon signed-rank test (and Generalized Estimating Equations).

It thus appears that responders in the experiment may have anticipated positive consequences from voting N in Period 1, but not negative consequences from voting Y. Whether these expectations are justified depends on proposer behavior. Is it true that proposers increase their offer after observing a No-vote and reduce it after a Yes-vote? Table 2.5 presents estimates from a linear regression model designed to address this question. The dependent variable is the number of points offered to a respective responder in Period 2. The explanatory variables include the Period 1 voting decisions of both the responder of interest and the other responder. In the public information case, we also include dummies indicating whether responders have a high breakdown value or not.¹⁵

Table 2.5 reveals that under private information, Period 2 offers are approximately 9 tokens higher when the respective responder voted N in Period 1, compared to a Yes-vote that resulted in a rejected proposal. When breakdown values are publicly known, the Period 1 vote does not significantly impact the size of the Period 2 proposal, which is instead determined by the breakdown values.¹⁷

Result U3. *Under unanimity rule and private information, P offers a larger share to a responder in Period 2 if that responder voted No than if they voted Yes in Period 1.*

Based on these estimates, it appears that responders in the experiment should have expected that voting N would lead to a higher Period 2 offer than voting Y. However, this effect was smaller than theoretically predicted (+8.6 instead of +35), which may help explain why responders appear to be less concerned about the *negative signaling value from voting Y* than the equilibrium analysis would predict.

¹⁵Note that each proposal appears twice in the regressions (once for responder 1 and once for responder 2). A more careful analysis, with separate regressions for each responder, is presented in Table 2.15, yielding very similar results.

¹⁶We expect the main source of correlation to be within individual proposers (refer to Fréchet (2012)). Fixed effects (of proposers) cannot be included because we lack sufficient observations.

¹⁷A high types obviously receive much larger offers. The effect of the other responder being high is negative: If I am high, then the other being high leads on average to a reduction of around 3 tokens. If I am low, then the other being high leads on average to a reduction of almost 7 tokens.

Table 2.5: Linear regression model: Period 2 offers (unanimity rule)

<i>Dependent variable: Offered points in Period 2</i>		
	Public info	Private info
	(1)	(2)
Constant	28.6*** (1.31)	41.9*** (0.85)
I voted Y	−0.06 (1.08)	−8.64*** (1.43)
Other voted Y	0.92 (1.08)	−1.36 (1.63)
I am high	17.5*** (1.44)	
Other is high	−6.83*** (1.40)	
Both are high	3.92** (1.56)	
Observations	238	250
R ²	0.73	0.17
Adjusted R ²	0.72	0.16
F Statistic	106*** (df=232)	18.6*** (df=247)

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variable is the offered tokens to the respective responder.

The exogenous variables are dummies.

Standard errors are clustered at the proposer level.¹⁶

2.5.2 Majority rule

Under majority rule, a voter is pivotal when included in a MWC. Table 2.6 presents the share of responders voting Y on the corresponding exogenous proposals. (For additional details on responders' Period 1 voting behavior, see Figures 2.10 and 2.11 for high types under public information, Figures 2.12 and 2.13 for low types under public information, and Figure 2.9 for the private information case.)

2. Multilateral bargaining with private information: Experiment

Table 2.6: Share of pivotal responders voting Yes (majority rule, high type)

proposal	Public Info		Private Info	
	$\delta = 1/6$	$\delta = 5/6$	$\delta = 1/6$	$\delta = 5/6$
(30,0)	0% (N)	0% (Y)	0% (N)	17% (Y)
(20,0)	8% (N)	0% (Y)	0% (N)	6% (Y)
(10,0)	11% (N)	0% (Y)	17% (N)	0% (Y)

Note: Y (N) indicates the voting behavior according to our equilibrium predictions.

These numbers are clearly inconsistent with our equilibrium predictions. Under both public and private information, high type responders consistently reject MWC proposals in which they are being offered less than their breakdown value, even when the continuation probability is large ($\delta = 5/6$). This result contradicts Hypothesis M1.

Result M1. *Under majority rule, high types vote No on MWC proposals that allocate less than their breakdown value to them, even when the continuation probability is high.*

A possible interpretation of Result M1 is that responders were not afraid that they would be excluded in Period 2. Let us look at Period 2 proposer behavior in order to explore whether the fear of exclusion is justifiably absent in the experiment. To investigate, Table 2.7 focuses on cases where responders voted N in Period 1 on an MWC that included them.

Table 2.7: Period 2 proposals after a MWC in Period 1 has been rejected

private	message	MWC w/ other	MWC w/ same	equal	other	total
Yes	Yes	36%	45%	9%	9%	11
Yes	No	36%	8%	44%	11%	36
No	Yes	36%	36%	18%	9%	11
No	No	30%	30%	12%	27%	33

Note: This table presents the percentages of Period 2 proposals in the following categories: MWCs that include the other responder compared to Period 1, MWCs that include the same responder as in Period 1, the equal proposal, and some other proposal. We also control for whether the proposer received a message from the responder that was included in Period 1.

Table 2.7 reveals that proposers do not react to rejection of a Period 1 MWC proposal

as theoretically predicted. Contrary to the equilibrium predictions, they form a MWC with the other responder in only about one third of the cases. This contradicts Hypothesis M2.

Result M2. *Under majority rule and private information, proposers rarely exclude a responder in Period 2 after they have voted No on a MWC that included them.*

Table 2.7 also shows that including a message alongside the Period 1 No-vote is advantageous when breakdown values are privately known. It raises the probability of P forming a MWC with the same responder from just 8% to 45%. Even in the absence of a message, the responder is excluded in only 36% of the observed cases. Instead, P proposes an equal split in nearly half of these cases. Thus, it appears that responders in the experiment did not have to fear exclusion as theoretically predicted. This pattern could help to explain the high rejection rates observed in Period 1.

As is typical of majoritarian bargaining experiments, the frequency of MWC proposals increases with experience (see Table 2.24), as does responders' likelihood to vote Y on such proposals (see Table 2.25). However, as is obvious from Table 2.7, the frequency of Yes-votes remains very low throughout.

2.5.3 Unanimity vs. majority rule

We now present the results on the hypotheses that compare the behavior under unanimity and under majority voting.

Exogenous proposals

Under majority rule, we have seen that the share of responders voting Y when included in a MWC is lower than predicted. For example, high-type responders virtually never vote Y, even when the continuation probability is large (see Result M1). Thus, behavior under majority rule resembles predicted behavior under unanimity rule. As an example, compare the proportion of pivotal responders voting Y when offered 20 under the two rules (see Table 2.8).

Table 2.8: Share of pivotal responders voting Yes (private information, high delta)

$(20,46) / (20,0)$	low type	high type
Unanimity	27% (N)	6% (N)
Majority	39% (Y)	6% (Y)

Note: Y (N) indicates the voting behavior according to our equilibrium predictions.

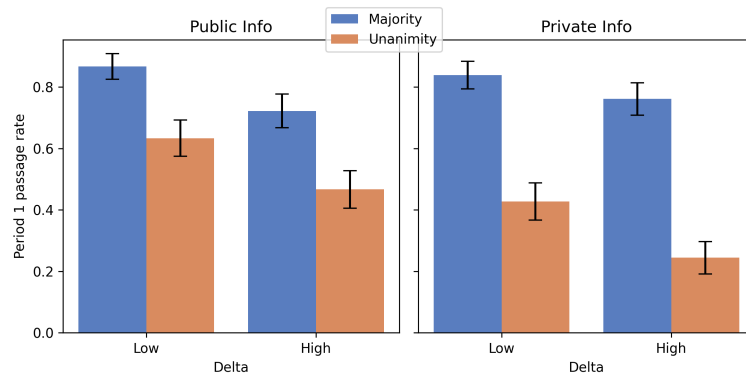
Clearly, the decision rule appears to have no effect on the likelihood that a pivotal high type votes Y when offered 20. For low types, the share voting Y is larger under majority rule, but this difference is not statistically significant (see Table 2.22). Thus, these numbers do not support Hypothesis UM1.

Result UM1. *Under private information and high continuation probability, pivotal responders are not significantly more likely to vote Yes when offered 20 under majority rule as compared to unanimity rule.*

Agreement probabilities

Figure 2.1 presents the probabilities of an immediate agreement in Period 1 if the endogenous proposal were always be selected (see Table 2.27 for the exact numbers).

Figure 2.1: Mean Period 1 agreement probabilities



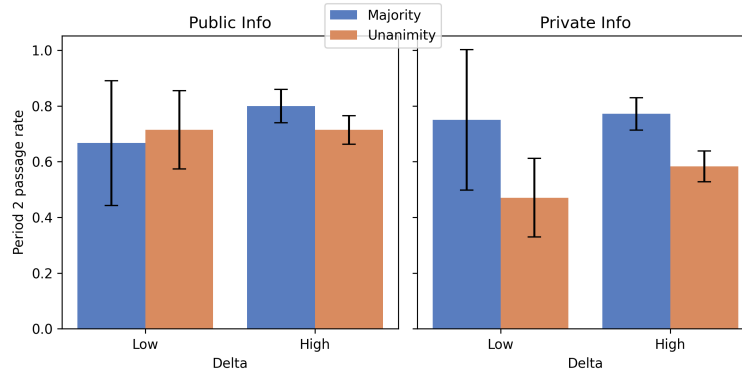
Note: This figure depicts the mean Period 1 agreement probabilities of the endogenous proposal contingent on the voting rule applied, the information available, and the continuation probability. 90% confidence intervals are included. For the exact numbers refer to Table 2.27.

Consistent with Hypothesis UM2, we observe a higher rate of agreement under majority

rule compared to unanimity rule. The differences are most pronounced in case of private information, being potentially due to signaling incentives. Specifically, under unanimity rule, we observe reduced agreement levels in scenarios involving private information or a large continuation probability. This observation reinforces the significance of signaling incentives, especially within the context of unanimity voting, thereby supporting Hypothesis U1.

Result UM2. *Period 1 agreement rates are higher under majority rule than under unanimity rule. The difference is most pronounced under private information and $\delta = 5/6$.*

Figure 2.2: Mean Period 2 agreement probabilities



Note: This figure depicts the mean Period 2 agreement probabilities of the endogenous proposal contingent on the voting rule applied, the information available, and the continuation probability. 90% confidence intervals are included. For the exact numbers refer to Table 2.28.

Figure 2.2 presents the Period 2 agreement rates. Note that in Period 2, signaling incentives are absent. Perhaps as a result of this difference, the disparities in the passage rates between the two voting rules diminish (for the exact numbers, refer to Table 2.28). They remain present only in the high-delta and private-information case. This potentially may be due to the fact that reaching an agreement under majority voting should be inherently less demanding, as fewer responders are required for an agreement to occur.

Messages

In total, 712 messages have been sent between the subjects (344 on endogenous proposals and 368 on exogenous proposals), out of 5760 possible messages. The majority of these messages were sent alongside a No-vote (74%) and within the private information environment (59%).

We used ChatGPT to categorize these messages. First, we provided ChatGPT with all the messages that had been sent and asked it to suggest a set of categories. ChatGPT then assigned each message to one of the suggested categories. In a final step, we manually reviewed the classifications to ensure that each message was indeed placed in the most appropriate category. Table 2.9 summarizes the resulting categorization.

Table 2.9: Categorized messages (unanimity rule, private information)

Category	Unan		Maj		Typical message ¹⁸
	Pub	Priv	Pub	Priv	
Request for 45 points or more	32%	43%	11%	27%	I get 45 if breakdown
Request for a minimum offer below 45	15%	6%	14%	24%	at least 40
Request for fair / equal distribution	10%	4%	20%	17%	divide fair
Positive feedback and agreement	18%	16%	17%	13%	nice
Negative feedback and disagreement	17%	20%	27%	14%	rude
Miscellaneous	7%	11%	11%	5%	hi
Total	117	193	178	224	

Note: This table presents the shares of messages assigned to each category. The values are rounded to the nearest whole number. The categorization was performed by ChatGPT (see main text for details).

Consistent with Hypothesis UM3, subjects under unanimity rule more frequently request the high type’s breakdown value in the private information setup compared to the public one. Similarly, they ask for the high share more often under unanimity rule than under majority rule ($p < 0.01$, see Table 2.26).¹⁹ However, such requests do accompany approximately 1/4 of No votes even under majority rule. Thus, Hypothesis UM3 is only partially supported.

¹⁸We translated these “typical” messages from German into English.

¹⁹The p-value is 0.0005 when doing a two-proportion z-test. (Recall that our samples for majority and unanimity rule are independent.)

Result UM3. *Under private information, messages indicating that a responder has a high breakdown value are more frequent under unanimity rule. However, such messages are also sent under majority rule.*

Conversely, the fair or equal distribution is more commonly requested under majority rule than under unanimity rule ($p < 0.05$ with public and $p < 0.01$ with private information, see Table 2.26). This indicates that fairness concerns may play a more prominent role under majority voting, as discussed in greater detail in Section 2.6.

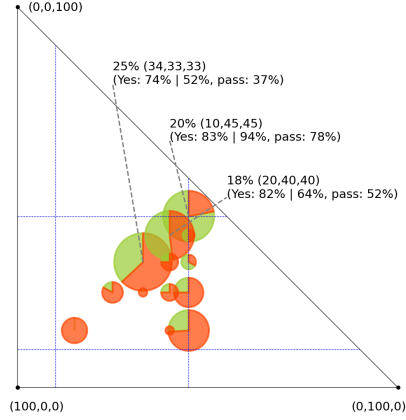
Endogenous proposals

Figure 2.3 displays the distribution of endogenous Period 1 proposals in the private information environment. (For the public information environment, see Figures 2.5, 2.6, and 2.7.) The data have been reshaped such that the responder being offered the larger share is responder 1. His offer is measured along the horizontal axis, and the offer to responder 2 is measured on the vertical axis. To make these figures more readable, proposals are clustered into categories.²⁰ For example, the proposal (36, 18, 46) is represented at the point (40, 15, 45), together with similar proposals. The size of each bubble is proportional to the number of proposals that fall into that cluster. The green (red) portion of a bubble corresponds to the share of proposals that passed (failed). The three most frequently observed proposals are labeled, with the percentage of the first and second responders who voted Y shown in parentheses.

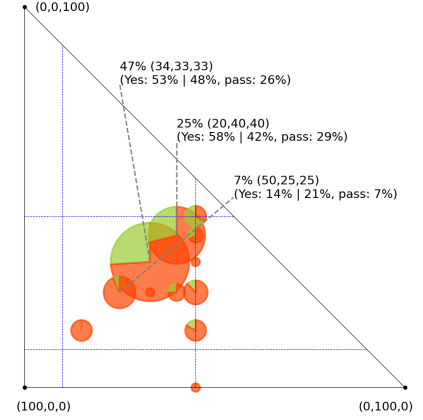
In all four cases shown in Figure 2.3, equal splits are the most common. Under majority rule, such proposals are highly likely to pass. Under unanimity rule, equal splits fail most of the time. Under majority rule, MWCs correspond to points along the horizontal axis. Such proposals account for only about one-third of the cases, contrary to theoretical predictions. These proposals are usually rejected if the included responder is offered less than an equal share.

²⁰Specifically, we categorized the shares allocated to a responder into bins with cutoffs at 10, 20, 30, 35, and 45 (e.g., the second bin includes all shares weakly above 10 and strictly below 20). All offers assigned to a particular bin are represented at a single point, with coordinates of 0, 15, 25, 33, 40, and 45.

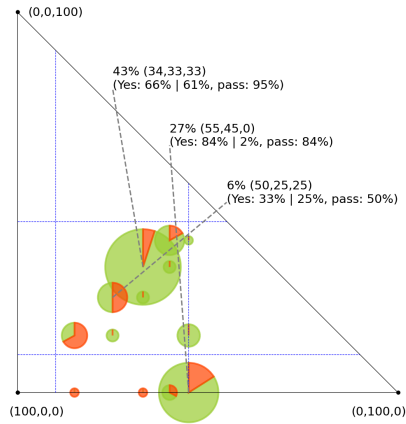
Figure 2.3: Period 1 proposals (private information)



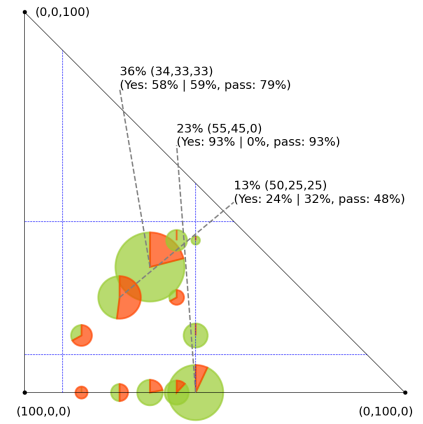
(a) Unanimity rule and low delta



(c) Unanimity rule and high delta



(b) Majority rule and low delta



(d) Majority rule and high delta

Note: This figure shows the Period 1 proposals endogenously chosen by P and the respective voting Yes and agreement probabilities. The size of the bubbles corresponds with the frequency of an proposal. There, red means rejected, green means accepted. Offers are clustered and ordered such that R1 faces the (weakly) larger share.

As we have already documented, endogenous proposals are in general more likely to pass under majority rule than under unanimity rule, especially when the continuation probability is low, reinforcing Result UM2. Under unanimity rule, we observe a higher passage rates at low delta, compared to high delta (compare Figure 2.3(a) and 2.3(c)). This aligns with our theoretical predictions and Result U1, which was based on exogenous proposals. Under majority rule, the equilibrium predictions involve higher acceptance rates when δ is large (see Hypothesis M1). However, the do not support this prediction (compare Figures 2.3(b) and 2.3(d)). This is consistent with Result M1 for exogenous proposals.

2.6 An ex-post approach to explain observed deviations

As we have documented, the experimentally observed differences between unanimity and majority voting are smaller than predicted by our equilibrium analysis. The main deviations from equilibrium predictions occur under majority rule. In particular, responders are more expensive than anticipated, and most proposers do not build MWCs or exclude those who reject such proposals. These deviations mean that behavior under majority rule is more similar to what was predicted for unanimity rule. A natural candidate to explain these deviations might be that subjects exhibit fairness concerns or other regarding preferences. This section discusses a deliberately simple modification to our modeling assumptions to demonstrate that the presence of fairness concerns is likely to affect behavior under majority rule more than it does for unanimity rule.

The intuition motivating this analysis is that the presence of fairness concerns, even for only a subset of participants, may lead to mutually reinforcing deviations from the predictions based on self interested rationality. If proposers expect responders to have fairness concerns, they may rationally refrain from proposing MWCs because the included responder may vote N out of concern for the other or because the proposal is viewed as an unkind act. Furthermore, proposers themselves may prefer equal distributions. If so, responders will be less concerned about the possibility of exclusion in Period 2, and thus

more likely to reject “unfair” proposals in Period 1, thus reinforcing the proposer’s incentive to make a “fair” proposal from the outset.

While these motivations and the resulting changes in expectations and incentives could be modeled by introducing distributional or reciprocity preferences, our approach will be more modest. For the sake of simplicity, and to focus on illustrating how these modifications affect predictions under the two rules differently, we will assume that a certain fraction ϵ of players are egalitarian “behavioral types” who follow a simple strategy: vote Y if and only if the proposal allocates at least $1/3$ to each responder and always propose the equal share when in the role of the proposer. The remaining $(1 - \epsilon)$ are “rational” types identical to those in the original model. The details of the analysis are presented in Appendix 2.B.²¹

To illustrate how the modification affects predictions differently depending on the rule, suppose for a moment that the fraction of behavioral types is $\epsilon = 1/2$, and consider the voting decision of a pivotal responder being offered some amount $x < 33$.

Under unanimity rule, the theoretical predictions for a responder facing a proposal of the form $(x, 46)$ (with $x < 33$) closely resemble those with “rational” types only. In the absence of behavioral types, a pivotal responder expects to be offered the high breakdown value in Period 2 if he votes N in Period 1, and he expects this Period 2 proposal to pass with probability $1/2$.²² Similarly, if half of the players have egalitarian preferences, the same responder can instead expect to be offered one-third of the pie in Period 2, and this proposal will now pass for sure.²³ As a result, the expected future tokens are quite similar in both scenarios, leading to comparable Period 1 prices, as shown in Table 2.10.

²¹It is important to note a significant issue with applying this adjusted model to our experimental results. In the theoretical framework, responders only face proposals made by P, whereas the experiment also includes proposals generated by the computer. Responders are unaware of which of the two Period 1 proposals is designed by P. Nonetheless, we are still optimistic that the presented adjusted model enhances our understanding of participants’ behavior.

²²The Period 2 proposal will allocate l to the other responder, and he will vote Y only if he is a low type.

²³This is because R2 will vote Y for sure. If he voted Y on $(x, 46)$ in Period 1, this reveals that he is selfishly rational, in which case he is offered h in Period 2. If he voted N in Period 1, this signals that he is egalitarian, and P will thus propose $(33, 33)$ in Period 2.

Table 2.10: Adjusted responders' Period 1 prices

$(x, 45)$	Unanimity rule			
	$\delta = 1/6$		$\delta = 5/6$	
	low type	high type	low type	high type
$\epsilon = 0$	12.9	45	24.6	45
$\epsilon = 1/2$	13.9	45	29.4	45

$(x, 0)$	Majority rule			
	$\delta = 1/6$		$\delta = 5/6$	
	low type	high type	low type	high type
$\epsilon = 0$	8.33	37.5	1.66	7.5
$\epsilon = 1/2$	13.9	43.5	29.4	37.7

Note: This table lists the lowest offers a respective responder would vote Y on, given that the other responder is offered 45 tokens under unanimity rule and zero tokens under majority rule. Players believe fellow players to be of an “egalitarian” type with probability $\epsilon = 1/2$, whereas the types (rational or egalitarian) as well as breakdown values are of private information. The prices of our original model coincide with the ones where $\epsilon = 0$.

Although the introduction of egalitarian types seems to only have a small effect under unanimity rule, an interesting finding emerges: For many proposals, the *negative signaling value from voting Yes* diminishes with the presence of egalitarian types. This is because the proposer will often propose an equal split in Period 2, reducing the costs incurred by a responder who votes Y when the other votes N (in our original model, this pattern would lead to being offered the low type’s share in Period 2).²⁴ As a result, the presence of a significant share of egalitarian players may explain why responders “rationally” choose to ignore *the negative signaling value from voting Yes*, as observed in our data.

In contrast, the changes under majority rule are far more substantial. Most notably, the threat of exclusion is reduced with the introduction of egalitarian players. Proposing a MWC becomes riskier, while proposing the equal share (33, 33) becomes more attractive.

²⁴The reasoning varies depending on the Period 1 vote. A Yes-vote might signal that a responder is likely egalitarian, leading to an equal proposal in Period 2. Alternatively, a Yes-vote could signal that the responder is a “rational” low type. However, Period 2 would only be reached if the other responder votes No, signaling they are likely egalitarian (especially if voting No on a high share), which would then also lead to the equal proposal in Period 2.

Consequently, if P expects only half of the responders to be rational, she will propose the equal proposal in Period 2. In Period 1, responders anticipate this and thus voting N on a Period 1 MWC is less risky than in the original model. This diminished fear of exclusion, particularly in the high-delta case, leads to higher Period 1 prices (see Table 2.10) and fewer MWCs being proposed.

The “adjusted” Period 1 price predictions for low type responders do not differ between the voting rules. Similarly, for high-type responders, the predicted price differences are much smaller than in our “original” model. These revised theoretical predictions align more closely with the observed behavior. For instance, consider the proposal $(20, 0)$ under majority voting. The new predictions match the observation that most low-type and nearly all high-type responders vote N on such proposals. While egalitarian types reject such MWCs by assumption, rational types now have additional reasons to do so as well: First, they may benefit from mimicking the behavior of egalitarian types. Second, their fear of exclusion is reduced (as evidenced by Table 2.7).

Notably, the introduction of a behavioral egalitarian type into our model provides a simple illustration of how predictions shift more substantially under majority rule compared to unanimity rule. An alternative approach would be to incorporate rational types with non-standard preferences, such as inequality aversion (Fehr and Schmidt (1999)), reciprocity (Falk and Fischbacher (2006)), or maximin preferences (Charness and Rabin (2000)). Intuitively, we would expect the inclusion of such preferences to yield only small changes under unanimity rule but more pronounced effects under majority rule. This is because unanimity voting inherently limits inequality, even in the absence of social preferences. However, prior work has shown that the application of standard social preference in multilateral bargaining models may also yield unexpected results. For instance, Montero (2007) shows that under certain conditions in the inequality-aversion model by Fehr and Schmidt (1999), the fear of exclusion might even intensify with inequality-averse players. In cases where the envy parameter is particularly strong, MWCs could become more frequent, and

responders may become less expensive. To gain a clearer understanding, further research is needed on bargaining under private information with “non-rational” players.²⁵

2.7 Concluding remarks

In this article, we have experimentally investigated behavior in a three-person, two-period bargaining game under different voting rules. Specifically, we compared behavior under majority and unanimity voting, with public or private information about breakdown values, and with either low or high continuation probabilities δ . Our key equilibrium predictions, based on the theoretical analyses of our companion paper (see Piazzolo and Vanberg (2024a)), suggest that responders are more expensive under unanimity rule than under majority rule, with the difference being especially pronounced when breakdown values are privately observed and the continuation probability is high. These variations in voting behavior between the two rules are largely driven by different signaling incentives. While under unanimity voting it is advantageous to signal a high breakdown value by voting No, doing so under majority voting can be costly due to the increased threat of exclusion from a Period 2 coalition. This logic motivates the prediction that responders will often vote No on offers above their breakdown value under unanimity rule and to vote Yes on offers below their breakdown value (even “peanuts”) under majority rule.

Under unanimity rule, the voting behavior of our laboratory participants largely aligns with the theoretical predictions. We observe that responders vote No more frequently when breakdown values are privately known and when the continuation probability is high. Additionally, in the messages responders were allowed to send, they most often requested the high share in the unanimity rule and private information environment. These findings clearly indicate that responders understand the *positive signaling value from voting No*

²⁵For instance, consider situations with uncertainty about the future behavior of bargaining partners, players lacking the ability to fully grasp future outcomes, or expecting others to lack this ability. We speculate that in such cases, players tend to “underestimate” the threat of exclusion under majority rule (compared to theoretical predictions), whereas under unanimity rule, there is less room for such significant misjudgments, ultimately leading to less variations between the two voting rules.

under unanimity rule and private information. However, we do not observe evidence that responders account for the predicted *negative signaling value from voting Yes*. Despite the fact that voting Yes in Period 1 results in significantly lower Period 2 offers, responders more frequently vote Yes on the equal proposal — where a Yes-vote is more likely to not lead to an immediate agreement — than on the pivotal (30, 46) proposal.²⁶

Under majority rule, our findings suggest that responders do not fear exclusion as much as theoretically predicted. Virtually no responder voted Yes on a proposal that offers them less than their breakdown values, even when the continuation probability is high and the threat of exclusion should therefore be strongest. These deviations from the theoretically predicted voting patterns can be partially explained by the behavior of proposers. Proposers form far fewer minimum winning coalitions than expected, and even when they do, they often do not exclude a responder who previously was offered a MWC and voted No on it.²⁷ Additionally, responders frequently succeed in using a message to secure a place in the Period 2 minimum winning coalition, even after signaling that they are a high type.

In sum, responders appear to consider the *positive signaling value from voting No* under unanimity rule. However, their voting behavior suggests that they do not account for *negative signaling values*, which can arise from voting No under majority rule or voting Yes under unanimity rule (if the other responder votes No). A possible explanation for these deviations is that experimental subjects are motivated by fairness concerns. To investigate this, we conducted an ex post theoretical exercise involving the introduction of egalitarian behavioral types into our model. The main insight from that analysis is that the presence of such types has a relatively larger impact on equilibrium behavior under majority rule, moving it in the direction of unanimity and thus reducing the differences between the rules.

²⁶This might also be due to fairness concerns. However, the observation that almost all high type responders vote No on the equal proposal (at $\delta = 5/6$) indicates that fairness concerns play only a minor role under unanimity voting (see Table 2.17).

²⁷Despite the fact that, by Bayes' rule, such a responder is more likely to be of a high type than a responder who voted No on a MWC that excluded him.

Another factor that may have contributed to the deviations observed is that subjects may be more accustomed to unanimity rule in their everyday experiences. Most day-to-day interactions are private and fully voluntary. Therefore these interactions depend on consensus and negotiations are - usually implicitly - governed by unanimity rule. Some subjects may therefore apply intuitions and heuristics appropriate to a unanimity rule setting even when majority rule is used. As in the case of fairness concerns, the implied behavioral adaptations could be self-reinforcing, as it becomes rational for participants to *anticipate* that others will behave as if unanimity rule is being applied, e.g., by not building MWCs.²⁸

Even though responders are more expensive under majority voting than initially predicted, we still find that inefficient breakdowns are significantly more likely under unanimity voting. The difference across voting rules is most pronounced when the continuation probability is high and private information is present, highlighting the importance of signaling incentives under unanimity rule. Importantly, this paper is only a first step toward understanding the distinct effects of private information under different voting rules. For example, bargaining situations with private information involving more than three players would introduce additional signaling dynamics, particularly under majority voting. In such cases, players might have added incentives to vote Yes to signal that they are “cheap”, thereby increasing their chances of being included in a Period 2 minimum winning coalition.²⁹ Also, the effect of building more stable “oversized” coalitions on the responders’ signalling incentives and willingness to vote Yes would be interesting to examine. Theoretical and experimental analyses of these more complex setups are left for future research.

²⁸For a detailed theoretical analysis of the effects of “non-rational” responders on the voting behavior under both unanimity and majority rule, see Piazzolo (2024). He shows that the presence of an unreliable responder leads to fewer MWCs being proposed under majority rule and responders becoming more expensive under both of the voting rules.

²⁹Recall that in our three-player setup, a Yes-vote leads to a guaranteed immediate agreement under majority rule.

Appendix

2.A Experiment

2.A.1 Experimental design

Figure 2.4: Voting decision in Period 1

Runde 1 (Variante B)

Sie sind **Teilnehmer B**

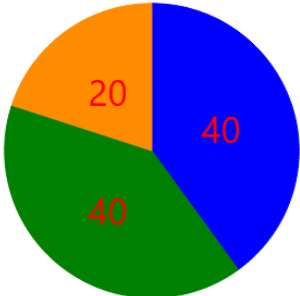
Ihre Auszahlung bei Abbruch: **10 Punkte**
(allen bekannt)

Auszahlungen bei Abbruch (**allen bekannt**)

Teilnehmer A	Teilnehmer B	Teilnehmer C
0 Punkte	10 Punkte	45 Punkte

Bitte treffen Sie für den folgenden Vorschlag eine Entscheidung

Vorschlag 1 von 2



● Teilnehmer A
● Teilnehmer B
● Teilnehmer C

Erinnerung: Ein ausgewählter Vorschlag gilt als angenommen, wenn Teilnehmer B und C beide mit Ja abgestimmt haben.

Ihre Entscheidung

Bitte treffen Sie jetzt eine Entscheidung.

Stimmen Sie diesem Vorschlag zu?

☐ Ja ☐ Nein

Nachricht (optional):

Weiter

2.A.2 Predictions

Table 2.11: Period 1 prices for pivotal responders (unanimity rule)

Types	Public info		Private info	
	$\delta = 1/6$	$\delta = 5/6$	$\delta = 1/6$	$\delta = 5/6$
	price L	price H	Type	
(H,H)		45	L	12.9
(L,L)	10		H	45
(L,H)	10	45		

Note: These tables list the theoretically determined Period 1 “prices” under unanimity rule on proposals where responders can expect their vote to be pivotal, i.e., the other responder votes Y with certainty, as he is offered 46.

Table 2.12: Period 1 prices for pivotal responders (majority rule)

Types	Public info		Private info	
	$\delta = 1/6$	$\delta = 5/6$	$\delta = 1/6$	$\delta = 5/6$
	price L	price H	Type	
(H,H)		37.5	L	8.33
(L,L)	8.33		H	37.5
(L,H)	10	37.5		

Note: These tables list the theoretically determined Period 1 “prices” under majority rule on proposals where responders can expect their vote to be pivotal, i.e., the other responder votes N with certainty, as he is offered 0.

³⁰Here, the theoretically predicted voting decision depends on the other responder’s breakdown value and the corresponding belief about a possible Period 2 proposal. For instance, a responder is predicted to vote Y if the other responder is of the low type because the high-type responder would then be certainly excluded in Period 2.

³¹Here, there is only an equilibrium in mixed strategies (besides the one where both responders vote N for sure). The low-type responders are expected to vote Y with probability $\bar{\mu} = \frac{2h+\tau-1}{\tau} = \frac{5}{7} \approx 0.714$ and high types are expected to vote N.

³²Here, there is no symmetric equilibrium in pure strategies, i.e., in a pure strategy equilibrium one of the responders is to vote Y for sure and the other is to vote N for sure.

Table 2.13: Voting predictions on exogenous Period 1 offers when pivotal

	$\delta = 1/6$				$\delta = 5/6$			
	low type		high type		low type		high type	
Breakdown values are of public info								
offer	unan.	maj.	unan.	maj.	unan.	maj.	unan.	maj.
30	Y	Y	N	N	Y	Y	N	Y
20	Y	Y	N	N	Y	Y	N	Y
10	Y	Y	N	N	Y	Y	N	Y
Breakdown values are of private info								
offer	unan.	maj.	unan.	maj.	unan.	maj.	unan.	maj.
30	Y	Y	N	N	Y	Y	N	Y
20	Y	Y	N	N	N	Y	N	Y
10	N	Y	N	N	N	Y	N	Y

Note: This table lists the theoretically predicted votes on the exogenously selected proposals. The proposals are such that responders can expect their vote to be pivotal, i.e., the other responder is offered 46 under unanimity rule and 0 under majority rule.

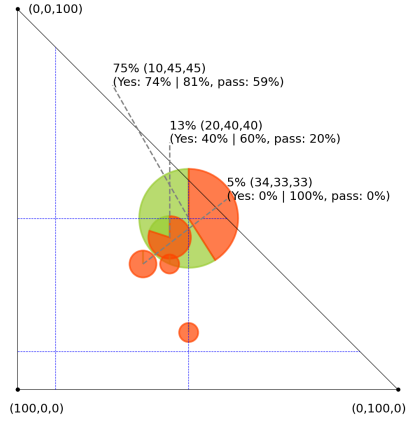
Table 2.14: Voting predictions on exogenous proposals that treat both equally

	$\delta = 1/6$				$\delta = 5/6$			
	low type		high type		low type		high type	
	Breakdown values are of public info							
offer	unan.	maj.	unan.	maj.	unan.	maj.	unan.	maj.
33	Y	Y	N	N	Y	Y	N	Y
20	Y	Y	N	N	Y	Y	N	? ³⁰
	Breakdown values are of private info							
offer	unan.	maj.	unan.	maj.	unan.	maj.	unan.	maj.
33	Y	Y	N	N	N	Y	N	Y
20	$\frac{5}{7}Y$ ³¹	Y	N	N	N	? ³²	N	? ³²

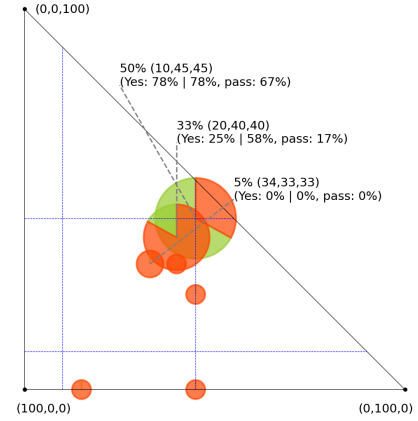
Note: This table lists the theoretically predicted votes on the exogenously selected proposals. The proposals are such that both responders face the same offer, i.e., either (33, 33) or (20, 20).

2.A.3 Proposer behavior

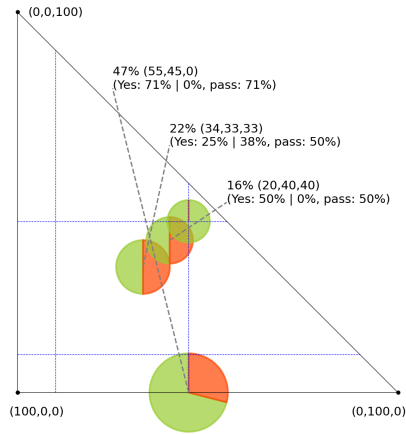
Figure 2.5: Period 1 proposals (public information, both high)



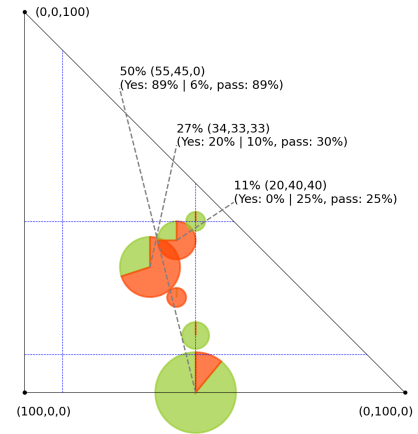
(a) Unanimity rule and low delta



(c) Unanimity rule and high delta



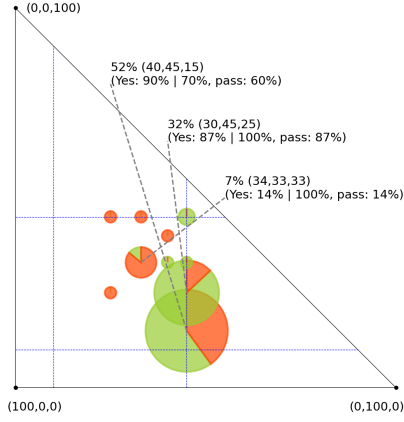
(b) Majority rule and low delta



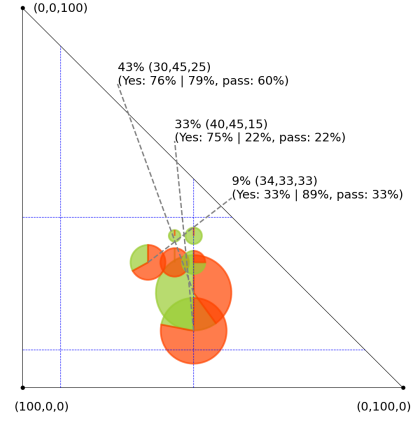
(d) Majority rule and high delta

Note: This figure shows the Period 1 proposals endogenously chosen by P and the respective voting Yes and agreement probabilities. The size of the bubbles corresponds with the frequency of a proposal. There, red means rejected, green means accepted. Offers are clustered and ordered such that R1 faces the (weakly) larger share. Both responders breakdown values are high.

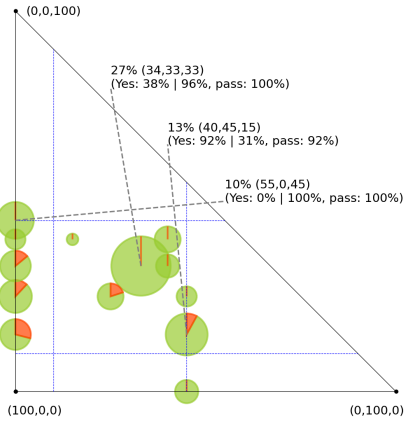
Figure 2.6: Period 1 proposals (public information, high and low)



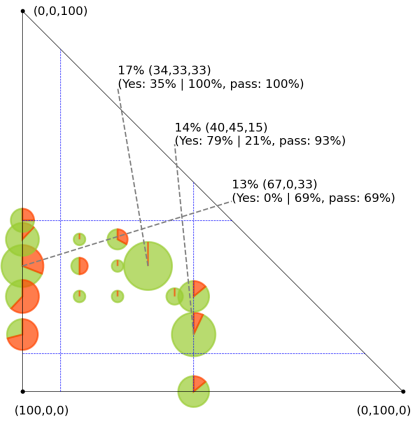
(a) Unanimity rule and low delta



(c) Unanimity rule and high delta



(b) Majority rule and low delta

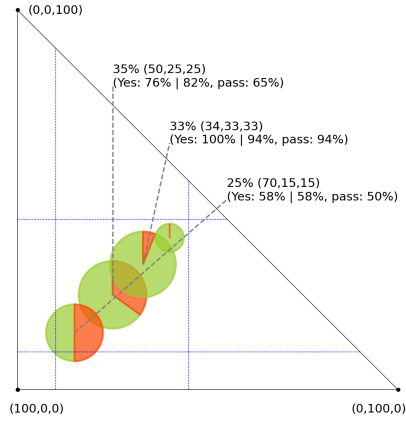


(d) Majority rule and high delta

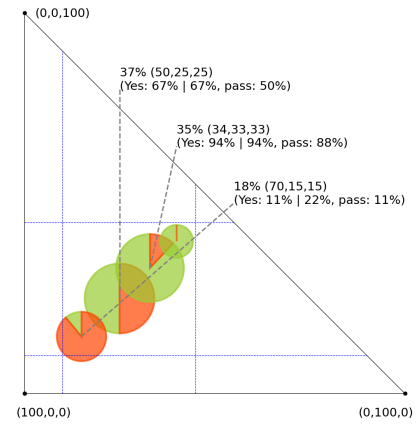
Note: This figure shows the Period 1 proposals endogenously chosen by P and the respective voting Yes and agreement probabilities. The size of the bubbles corresponds with the frequency of a proposal. There, red means rejected, green means accepted. Offers are clustered. R1's breakdown value is high, R2's is low.

2. Multilateral bargaining with private information: Experiment

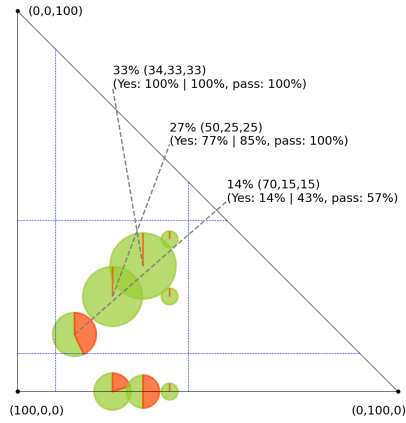
Figure 2.7: Period 1 proposals (public information, both low)



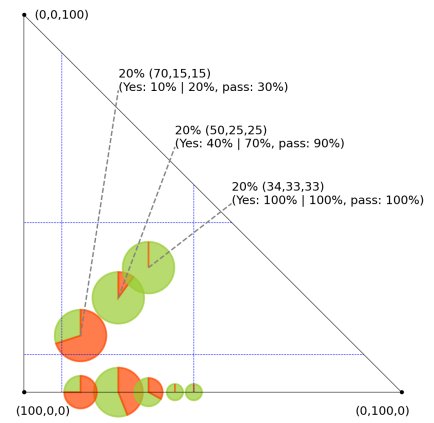
(a) Unanimity rule and low delta



(c) Unanimity rule and high delta



(b) Majority rule and low delta



(d) Majority rule and high delta

Note: This figure shows the Period 1 proposals endogenously chosen by P and the respective voting Yes and agreement probabilities. The size of the bubbles corresponds with the frequency of a proposal. There, red means rejected, green means accepted. Offers are clustered and ordered such that R1 faces the (weakly) larger share. Both responders breakdown values are low.

Table 2.15: Period 2 proposals (unanimity rule)

	<i>Dependent variable: Offered points in Period 2</i>			
	Public info		Private info	
	Offer to R1 (1)	Offer to R2 (2)	Offer to R1 (3)	Offer to R2 (4)
Constant	29.1*** (1.59)	27.2*** (1.53)	41.8*** (1.11)	42.1*** (0.92)
R1 voted Y	-1.28 (1.37)	1.98 (1.73)	-7.29*** (1.61)	-2.17 (1.55)
R2 voted Y	0.02 (1.36)	1.03 (1.50)	-0.62 (2.38)	-9.83*** (2.08)
R1 is high	15.2*** (2.52)	-5.01** (2.29)		
R2 is high	-8.08*** (1.53)	18.9*** (1.28)		
Both are high	6.60** (2.58)	1.38 (2.53)		
Observations	119	119	125	125
R ²	0.74	0.72	0.13	0.20
Adjusted R ²	0.73	0.70	0.12	0.19
F Statistic	74.4*** (df=113)	81.3*** (df=113)	10.7*** (df=122)	11.3*** (df=122)

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variable is the offered tokens to R1 or R2, respectively.

The exogenous variables are dummies = 1 if responder has voted Y in t=1 / if of high type.

Standard errors are clustered at the proposer level.³³

2.A.4 Responder behavior

Exogenous Period 1 proposals

Table 2.16: Share of pivotal responders voting Yes on exogenous Period 1 proposals

	$\delta = 1/6$				$\delta = 5/6$			
	low type		high type		low type		high type	
	Breakdown values are of public info							
offer	unan.	maj.	unan.	maj.	unan.	maj.	unan.	maj.
30	100% (Y)	63% (Y)	0% (N)	0% (N)	77% (Y)	73% (Y)	33% (N)	0% (Y)
20	92% (Y)	50% (Y)	17% (N)	8% (N)	71% (Y)	33% (Y)	8% (N)	0% (Y)
10	22% (Y)	6% (Y)	0% (N)	11% (N)	11% (Y)	6% (Y)	0% (N)	0% (Y)
	Breakdown values are of private info							
offer	unan.	maj.	unan.	maj.	unan.	maj.	unan.	maj.
30	97% (Y)	67% (Y)	17% (N)	0% (N)	57% (Y)	70% (Y)	17% (N)	17% (Y)
20	83% (Y)	44% (Y)	0% (N)	0% (N)	27% (N)	39% (Y)	6% (N)	6% (Y)
10	25% (N)	13% (Y)	0% (N)	17% (N)	13% (N)	0% (Y)	0% (N)	0% (Y)

Note: The table lists the shares of responders that vote Yes on the exogenously selected proposals. The proposals are such that responders can expect their vote to be pivotal, i.e., the other responder is offered 46 under unanimity rule and 0 under majority rule. The theoretically predicted votes are in parentheses.

2. Multilateral bargaining with private information: Experiment

Table 2.17: Share of responders voting Yes on exogenous proposals that treat both equally

	$\delta = 1/6$				$\delta = 5/6$			
	low type		high type		low type		high type	
	Breakdown values are of public info							
offer	unan.	maj.	unan.	maj.	unan.	maj.	unan.	maj.
33	100% (Y)	100% (Y)	17% (N)	43% (N)	97% (Y)	97% (Y)	10% (N)	41% (Y)
20	75% (Y)	54% (Y)	0% (N)	0% (N)	46% (Y)	44% (Y)	4% (N)	12% (? ³⁴)
	Breakdown values are of private info							
offer	unan.	maj.	unan.	maj.	unan.	maj.	unan.	maj.
33	100% (Y)	93% (Y)	24% (N)	24% (N)	70% (N)	97% (Y)	12% (N)	33% (Y)
20	72% ($\frac{5}{7}$ Y ³⁵)	47% (Y)	0% (N)	3% (N)	31% (N)	22% (? ³⁶)	3% (N)	3% (? ³⁶)

Note: This table lists the shares of responders that vote Yes on the exogenously selected proposals. The proposals are such that both responders face the same offer, i.e. either (34, 33, 33) or (60, 20, 20). The theoretically predicted votes are in parentheses.

Table 2.18: Wilcoxon rank-sum test: Low vs. high delta (unanimity rule, low type)

proposal	public info	private info
(30, 46)	$p < 5\%$	$p < 1\%$
(20, 46)	$p < 10\%$	$p < 1\%$
(10, 46)	$p > 10\%$	$p > 10\%$
(33, 33)	$p > 10\%$	$p < 10\%$
(20, 20)	$p < 10\%$	$p < 1\%$

Note: The table presents the p-values from the Wilcoxon rank-sum test, comparing the average shares of low types' Yes-votes per matching group on a given proposal under unanimity voting between $\delta = 1/6$ and $\delta = 5/6$. A p-value smaller than 10% indicates that the average share of Yes-votes per matching group is larger if $\delta = 1/6$ than if $\delta = 5/6$.

Table 2.19: Two-proportion z-test: Low vs. high delta (unanimity rule, low type)

proposal	public info	private info
(30, 46)	$p < 1\%$	$p < 1\%$
(20, 46)	$p < 10\%$	$p < 1\%$
(10, 46)	$p > 10\%$	$p > 10\%$
(33, 33)	$p > 10\%$	$p < 1\%$
(20, 20)	$p < 1\%$	$p < 1\%$

Note: The table presents the p-values from the two-proportion z-test, comparing the frequency of low types' Yes-votes on a given proposal under unanimity voting between $\delta = 1/6$ and $\delta = 5/6$. A p-value smaller than 10% indicates that a particular proposal is voted Yes on more often if $\delta = 1/6$ than if $\delta = 5/6$.

2. Multilateral bargaining with private information: Experiment

Table 2.20: Wilcoxon signed-rank test: Private vs. public information (unanimity rule, low type)

proposal	$\delta = 1/6$	$\delta = 5/6$
(30, 46)	$p > 10\%$	$p < 5\%$
(20, 46)	$p > 10\%$	$p < 5\%$
(10, 46)	$p > 10\%$	$p > 10\%$

Note: The table presents the p-values from the Wilcoxon signed-rank test, comparing the average shares of low types' Yes-votes per matching group on a given proposal under unanimity rule between private and public information. A p-value smaller than 10% indicates that the average share of Yes-votes per matching group is larger if breakdown values are of public than of private information.

Table 2.21: Generalized Estimated Equations: Private vs. public information (unanimity rule, low type)

proposal	$\delta = 1/6$	$\delta = 5/6$
(30, 46)	$p > 10\%$	$p < 10\%$
(20, 46)	$p < 10\%$	$p < 1\%$
(10, 46)	$p > 10\%$	$p > 10\%$

Note: The table presents the p-values from the generalized estimated equations, comparing the frequency of low types' Yes-votes on a given proposal under unanimity rule between private and public information. A p-value smaller than 10% indicates that a particular proposal is voted Yes on more often if breakdown values are of public than of private information.

Table 2.22: Wilcoxon rank-sum test: Unanimity vs. majority rule (private information, high delta)

pivotal offer	low type	high type
30	$p > 10\%$	$p > 10\%$
20	$p > 10\%$	$p > 10\%$
10	$p > 10\%$	$p > 10\%$

Note: The table presents the p-values from the Wilcoxon rank-sum test, comparing the average shares of Yes-votes per matching group on a given pivotal offer under private information and $\delta = 1/6$ between majority and unanimity voting. A p-value smaller than 10% indicates that the average share of Yes-votes per matching group is larger if majority than if unanimity rule is applied.

Table 2.23: Two-proportion z-test: Unanimity vs. majority rule (private information, high delta)

pivotal offer	low type	high type
30	$p > 10\%$	$p > 10\%$
20	$p > 10\%$	$p > 10\%$
10	$p > 10\%$	$p > 10\%$

Note: The table presents the p-values from the two-proportion z-test, comparing the frequency of Yes-votes on a given pivotal offer under private information and $\delta = 1/6$ between majority and unanimity voting. A p-value smaller than 10% indicates that a particular proposal is voted Yes on more often if majority than if unanimity rule is applied.

³³We expect the main source of correlation to be within individual proposers (refer to Fréchette (2012)). Fixed effects (of proposers) cannot be included because we lack sufficient observations.

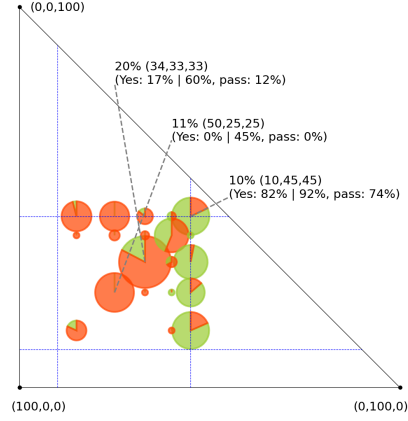
³⁴Here, the theoretically predicted voting decision depends on the other responder's breakdown value and the corresponding belief about a possible Period 2 proposal. For instance, a responder is predicted to vote Y if the other responder is of the low type because the high-type responder would then be certainly excluded in Period 2.

³⁵Here, there is only an equilibrium in mixed strategies (besides the one where both responders vote N for sure). The low-type responders are expected to vote Y with probability $\bar{\mu} = \frac{2h+\tau-1}{\tau} = \frac{5}{7} \approx 0.714$ and high types are expected to vote N.

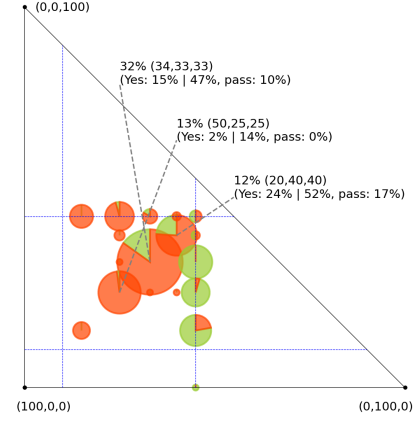
³⁶Here, there is no symmetric equilibrium in pure strategies, i.e., in a pure strategy equilibrium one of the responders is to vote Y for sure and the other is to vote N for sure.

All Period 1 proposals - private information

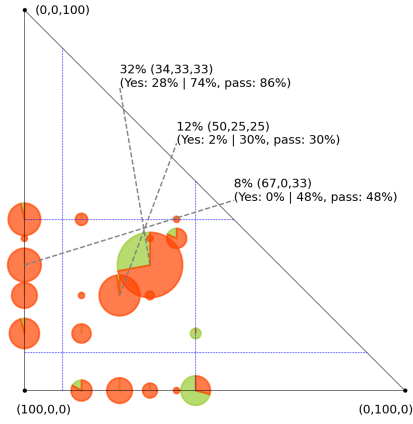
Figure 2.8: Voting on Period 1 proposals (private information, high type)



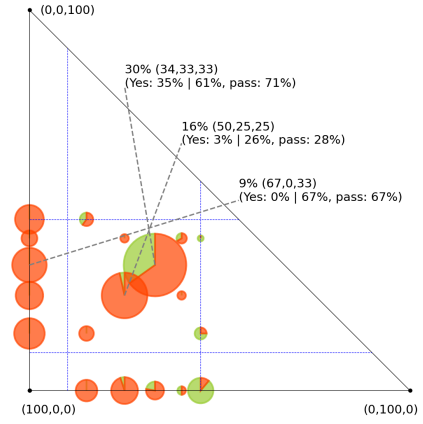
(a) Unanimity rule and low delta



(c) Unanimity rule and high delta



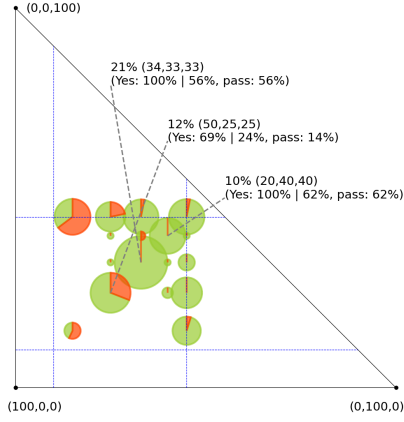
(b) Majority rule and low delta



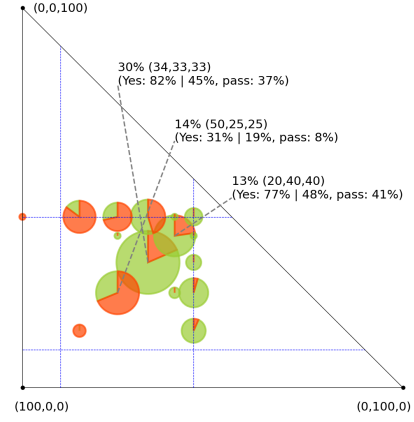
(d) Majority rule and high delta

Note: This figure shows the voting Yes and agreement probabilities on all Period 1 proposals. The size of the bubbles corresponds with the frequency of a proposal. There, red means R1 voted N, green means R1 voted Y. Offers are clustered. R1's breakdown value is high.

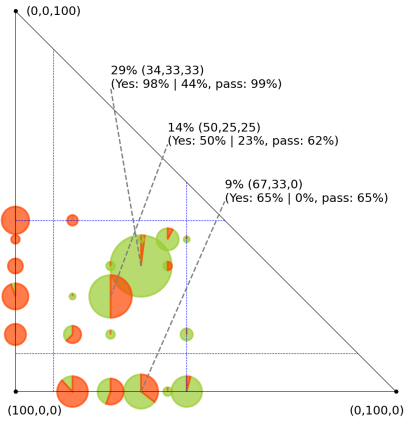
Figure 2.9: Voting on Period 1 proposals (private information, low type)



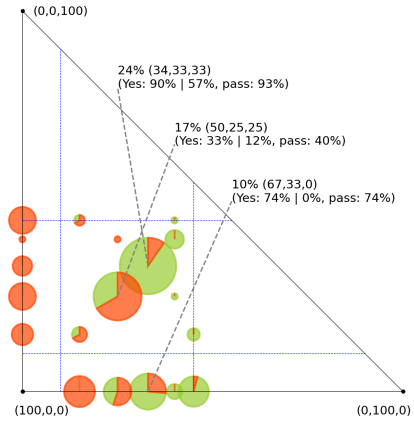
(a) Unanimity rule and low delta



(c) Unanimity rule and high delta



(b) Majority rule and low delta

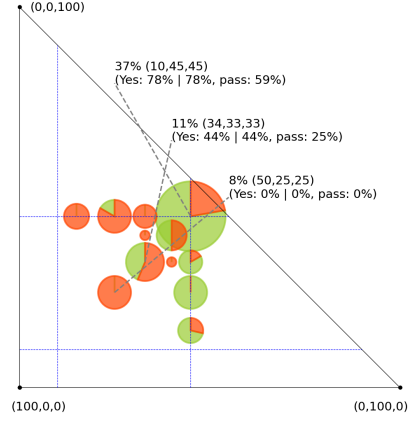


(d) Majority rule and high delta

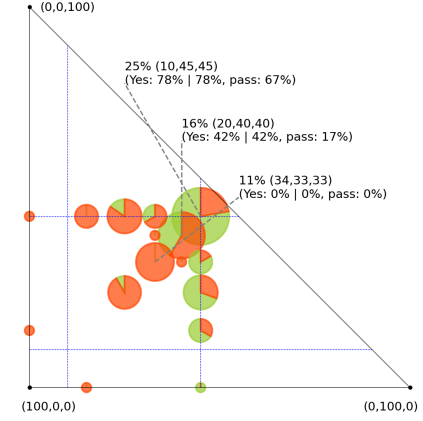
Note: This figure shows the voting Yes and agreement probabilities on all Period 1 proposals. The size of the bubbles corresponds with the frequency of a proposal. There, red means R1 voted N, green means R1 voted Y. Offers are clustered. R1's breakdown value is low.

All Period 1 proposals - public information

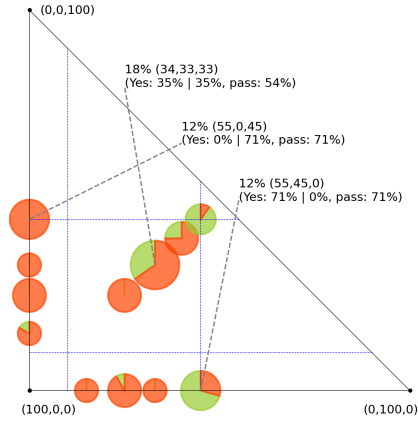
Figure 2.10: Voting on Period 1 proposals (public information, high type, other is high)



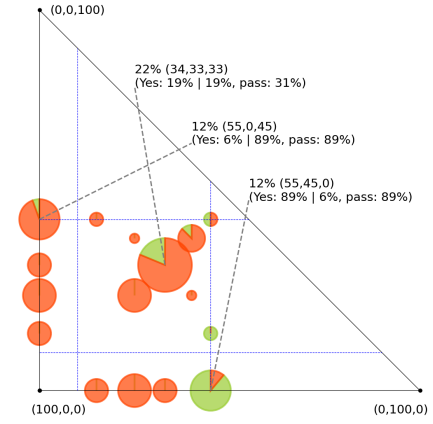
(a) Unanimity rule and low delta



(c) Unanimity rule and high delta



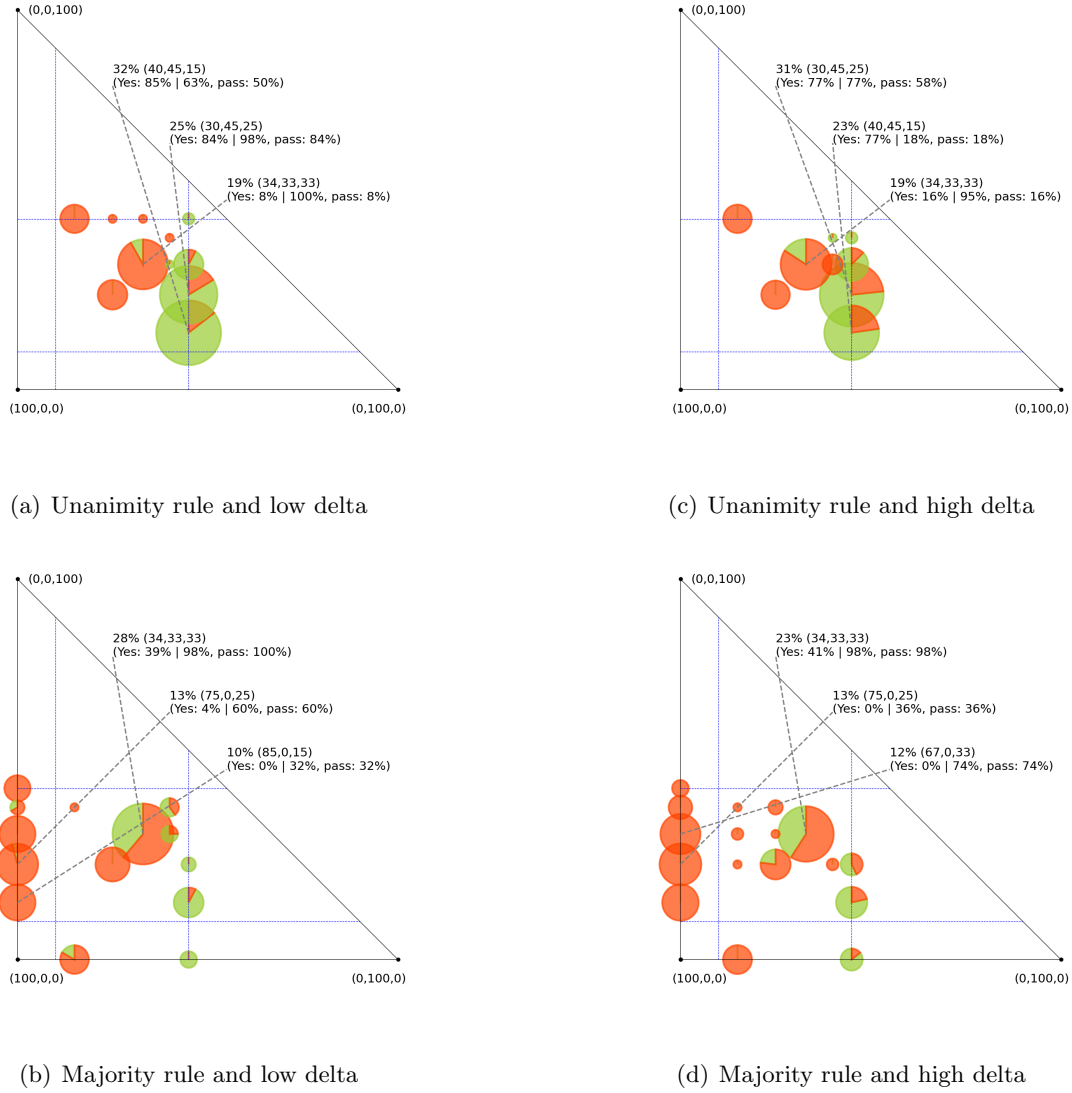
(b) Majority rule and low delta



(d) Majority rule and high delta

Note: This figure shows the voting Yes and agreement probabilities on all Period 1 proposals. The size of the bubbles corresponds with the frequency of a proposal. There, red means R1 voted N, green means R1 voted Y. Offers are clustered. Both responders breakdown values are high.

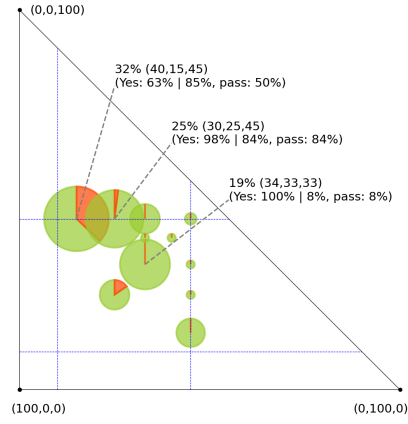
Figure 2.11: Voting on Period 1 proposals (public information, high type, other is low)



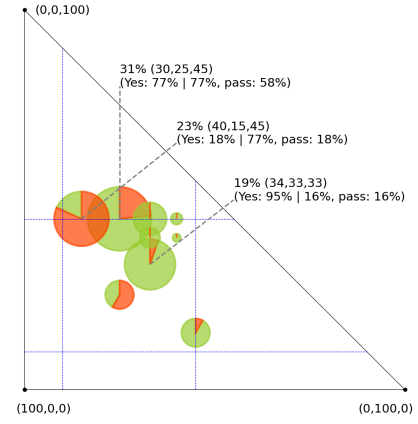
Note: This figure shows the voting Yes and agreement probabilities on all Period 1 proposals. The size of the bubbles corresponds with the frequency of a proposal. There, red means R1 voted N, green means R1 voted Y. Offers are clustered. R1's breakdown value is high, R2's is low.

2. Multilateral bargaining with private information: Experiment

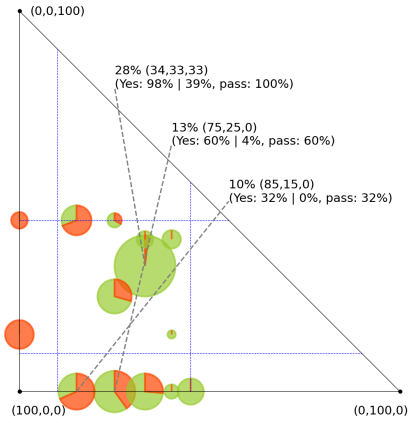
Figure 2.12: Voting on Period 1 proposals (public information, low type, other is high)



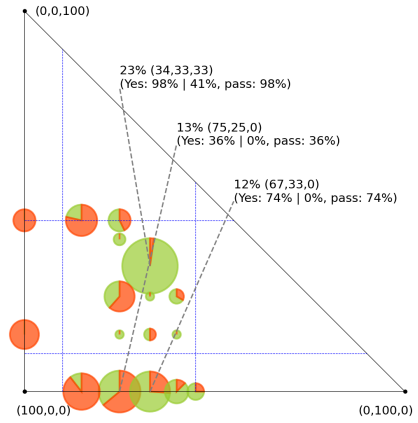
(a) Unanimity rule and low delta



(c) Unanimity rule and high delta



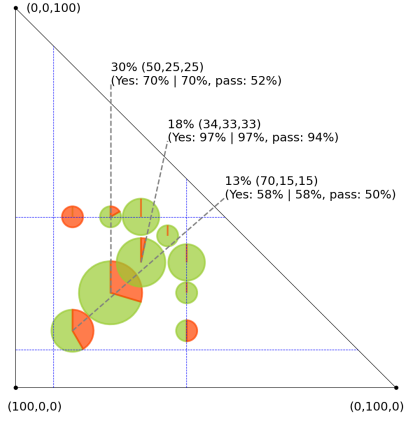
(b) Majority rule and low delta



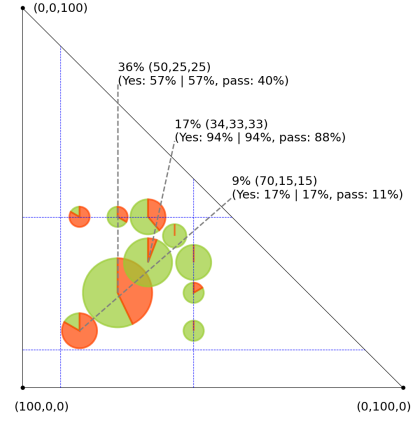
(d) Majority rule and high delta

Note: This figure shows the voting Yes and agreement probabilities on all Period 1 proposals. The size of the bubbles corresponds with the frequency of a proposal. There, red means R1 voted N, green means R1 voted Y. Offers are clustered. R1's breakdown value is low, R2's is high.

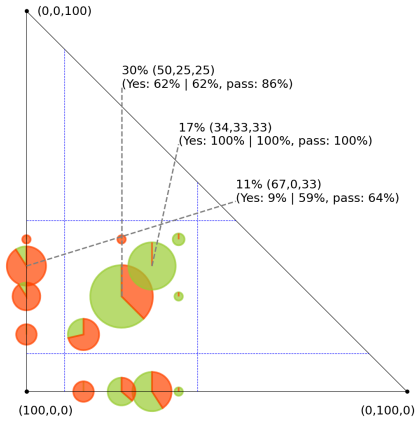
Figure 2.13: Voting on Period 1 proposals (public information, low type, other is low)



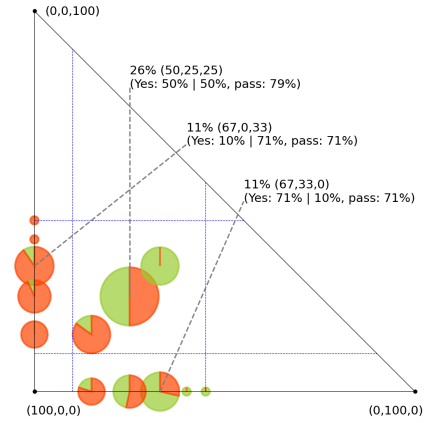
(a) Unanimity rule and low delta



(c) Unanimity rule and high delta



(b) Majority rule and low delta



(d) Majority rule and high delta

Note: This figure shows the voting Yes and agreement probabilities on all Period 1 proposals. The size of the bubbles corresponds with the frequency of a proposal. There, red means R1 voted N, green means R1 voted Y. Offers are clustered. Both responders breakdown values are low.

Minimum winning coalitions

Table 2.24: Proposing a MWC in Period 1

	<i>Dependent variable: Probability of a MWC being proposed</i>		
	Pooled	Public info	Private info
	(1)	(2)	(3)
Private info	−0.028 (0.033)		
High delta	0.050 (0.033)	0.067 (0.045)	0.033 (0.046)
Period	0.016*** (0.006)	0.019** (0.008)	0.012 (0.008)
First 10 rounds	0.097 (0.065)	0.101 (0.091)	0.077 (0.092)
One R is high		0.289*** (0.058)	
Both R are high		0.350*** (0.071)	
Constant	0.033 (0.094)	−0.248* (0.133)	0.068 (0.129)
Observations	720	360	360
R ²	0.021	0.109	0.011
Adjusted R ²	0.016	0.097	0.002
Residual Std. Error	0.438	0.426	0.433
F Statistic	3.882***	8.698***	1.269

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variable is a dummy = 1 if P proposes a MWC in t=1.

We control for individual fixed effects.

Standard errors are clustered at the individual level.³⁷

³⁷As we are using multiple time periods, we cluster by individual, since the unit of randomization is individual, and not individual-time period (see Abadie et al. (2023)).

Table 2.25: Voting Yes on a MWC in Period 1

	<i>Dependent variable: Probability of voting Yes</i>		
	Pooled	Public info	Private info
	(1)	(2)	(3)
Constant	−0.205 (0.107)	−0.077 (0.152)	−0.267* (0.149)
Private info	0.055* (0.029)		
High delta	−0.022 (0.030)	−0.073* (0.043)	0.031 (0.042)
Period	0.013** (0.006)	0.006 (0.008)	0.020** (0.008)
First 10 rounds	0.074 (0.066)	0.026 (0.094)	0.135 (0.094)
R is high	0.078** (0.035)	0.116** (0.052)	0.043 (0.048)
Other R is high		−0.005 (0.046)	
Offer in t=1 > b	0.685*** (0.036)	0.681*** (0.054)	0.697*** (0.048)
Observations	700	365	335
R ²	0.556	0.337	0.431
Adjusted R ²	0.471	0.325	0.422
F Statistic	6.57*** (df=112)	30.268***	49.864***

Note: *p<0.1; **p<0.05; ***p<0.01
The endogenous variable is a dummy = 1 if responder votes Y on MWC in t=1.
We control for individual fixed effects.
Standard errors are clustered at the individual level.

Messages

Table 2.26: Two-proportion z-test: More messages under the following voting rule

Message category	more messages with	public info	private info
Request for 45 or more	unanimity	$p < 1\%$	$p < 1\%$
Request for 44 or less	majority	$p > 10\%$	$p < 1\%$
Request for equal	majority	$p < 5\%$	$p < 1\%$
Agreement	unanimity	$p > 10\%$	$p > 10\%$
Disagreement	unanimity	$p > 10\%$	$p > 10\%$
Miscellaneous	unanimity	$p < 1\%$	$p > 10\%$

Note: The table presents the p-values from the two-proportion z-test, comparing the frequency of messages in a given category under one voting rule versus the other. A p-value smaller than 10% indicates that a particular type of message occurs significantly more often under the specified voting rule.

2.A.5 Agreement probabilities

Table 2.27: Period 1 passage probabilities of the endogenous proposal

	private info		public info	
	$\delta = \frac{1}{6}$	$\delta = \frac{5}{6}$	$\delta = \frac{1}{6}$	$\delta = \frac{5}{6}$
unanimity	43%	24%	63%	47%
majority	84%	76%	87%	72%

Note: This table lists the shares of endogenous proposals with a sufficient amount of responders voting Yes such that the proposal passes if it would be selected.

Table 2.28: Period 2 passage probabilities

	private info	public info
unanimity	57%	71%
majority	77%	79%

Note: This table lists the shares of Period 2 proposals where a sufficient amount of responders votes Yes such that the proposal passes.

2.B Adjusted model

In the following, let us discuss an adjusted model where not all players choose their voting decision by maximizing their expected payoffs. This will not only affect the behavior of the respective “new” types of players but also of the “payoff maximizers”, as they will have to take into account the changes in the behavior of the other group members. It will be interesting to see how these changes in voting behavior will differ between the applied voting rules.

2.B.1 Setup

We distinguish between “rational” and “egalitarian” players. While the former make their decisions by maximizing their expected payoffs, the latter always propose the equal proposal and vote Y iff facing at least the equal proposal, i.e., iff $x_1 \geq \frac{1}{3} \equiv e$ and $x_2 \geq e$ (with a pie size of 1). There, the ex ante probability that a player is of the egalitarian type is exogenously assumed to be ϵ . Period 2 beliefs about players’ types are determined by Bayes’ Rule and denoted by $\omega = (\omega_P, \omega_1, \omega_2)$. There, ω_P is the belief about P being of the egalitarian type. Similarly, $\omega_i = (a, b)$ is the belief about Ri, with a being the probability that Ri is of the egalitarian type and b the probability with that Ri is of the high type, given that he is rational. We are especially interested in the impact of introducing ϵ on responders’ prices and how this impact varies between the two voting rules. There, we focus on the case $\epsilon = 1/2$, i.e., half of the players are of the egalitarian type and the other half is of the rational type.

Note that there is a big problem with applying the adjusted model to our experimental results. In our theory responders only face proposals that are designed by P. Thus, they can perfectly infer that P cannot be of the egalitarian type if facing an unequal proposal. In contrast to that, the experiment also includes proposals made by the computer. The responders do not know which of the two proposals they face in Period 1 is of the proposer.

Therefore, they learn less about the proposer's type than in the theoretical model. This impacts signaling values and thus Period 1 prices. For simplicity, we ignore these differences in the following analysis, and are optimistic that the analysis still serves its purpose in enhancing our understanding of the lab participants' behavior.

Let us for now assume that $h \in (\frac{1}{3}, \frac{1}{2})$ and $l \in (0, \frac{1}{3})$ - just as in our experiment. Note that we do not attempt a full equilibrium analysis but focus on two specific situations of interest (similar to the exogenously introduced proposals in our experiment): Under unanimity rule, one of the responders votes Y with certainty (if rational) and under majority rule, one of the responder is excluded (MWC).

2.B.2 Unanimity rule: A pivotal proposal

Let us take a look at a Period proposal of the form $x^1 = (x_1^1, h)$. That is, the R2 will vote Y with certainty if he is rational and Y whenever $x_1^1 \geq e$ if he is of the egalitarian type. Also, P must be of the rational type (otherwise she would have proposed the equal share).

Other votes Y for sure On equilibrium path, P will then either propose (z_L, h) , (e, h) , or (h, h) in Period 1. We are particularly interested in R1's voting behavior if he is of the rational and low type, i.e., in R1's Period 1 price z_L . We therefore assume that P proposals (z_L, h) in Period 1. There, we differentiate between two cases: $z_L \geq e$ and $z_L < e$.

First, suppose $z_L > e$. Then, R1 can be sure that R2 votes Y. Consequently, Period 2 will only be reached after R1 has voted N, yielding Period 2 beliefs of $\omega = (0, (0, 1), (\epsilon, \frac{1}{2}))$. P will then either propose (h, l) or (h, e) . (We assume that h is sufficiently large such that the (h, h) is never optimal - like in the experiment.) P's expected Period 2 utility is $\frac{1-\epsilon}{2}(1 - h - l)$ in the former case and $\frac{1+\epsilon}{2}(1 - h - e)$ in the latter one. The former utility is larger if $\epsilon < \frac{e-l}{2-2h-e-l}$ (i.e., if $\epsilon < 0.35$ in our experiment).

If $\epsilon < \frac{e-l}{2-2h-e-l}$, P proposes (h, l) in Period 2. Then R1's utility from voting voting N is $l + \delta \frac{1-\epsilon}{2}(h - l)$, whereas his utility from voting Y simply amounts x . If $\epsilon > \frac{e-l}{2-2h-e-l}$,

P proposes (h, e) in Period 2. Then R1's utility from voting voting N is $l + \delta \frac{1+\epsilon}{2}(h - l)$, whereas his utility from voting Y still amounts x . The low type's price, given that the other votes Y in all three cases (if egalitarian, if rational and low, and if rational and high) and given that $z_L \geq e$, thus is $z_L^u(1, 1, 1) = \begin{cases} l + \delta \frac{1-\epsilon}{2}(h - l) & \epsilon < \frac{e-l}{2-2h-e-l}, \\ l + \delta \frac{1+\epsilon}{2}(h - l) & \epsilon > \frac{e-l}{2-2h-e-l}. \end{cases}$ Note that for the parameters of our experiment, $l + \delta \frac{1-\epsilon}{2}(h - l) < e$ (a contradiction). $l + \delta \frac{1+\epsilon}{2}(h - l) > e$ only holds in case $\delta = \frac{5}{6}$ and $\epsilon > 0.6$. That is, given that $\epsilon = 1/2$, no such proposal exists on the equilibrium path, where $z_L > e$.

Second, suppose $z_L < e$. Then R2 votes Y with probability $1 - \epsilon$. Consequently, we must differentiate between the different options of how Period 2 might be reached:

- If only R1 has voted N (while R2 has voted Y), the Period 2 beliefs amount $\omega = (0, (\frac{2\epsilon}{1+\epsilon}, 1), (0, \frac{1}{2}))$.³⁸ P will then either propose (h, l) or (e, h) .³⁹ (We assume that h is sufficiently large such that the (h, h) is never optimal - like in the experiment.) One can show that the former is preferred if $\epsilon < \frac{1-h-l}{4-5h-e-l}$ ($= \frac{27}{79}$ in our experiment).
- If only R2 has voted N (and R1 voted Y), the Period 2 beliefs are $\omega = (0, (0, 0), (1, \frac{1}{2}))$. P will then propose (e, e) .
- If both have voted N, Period 2 beliefs are $\omega = (0, (\frac{2\epsilon}{1+\epsilon}, 1), (1, \frac{1}{2}))$. P will then propose (e, e) or (h, e) . One can show that the former is preferred if $\epsilon > \frac{1-h-e}{h}$ ($= \frac{13}{27}$ in our experiment).

Suppose that half of the responders are of the egalitarian type ($\epsilon = 1/2$) and take $l = 0.1$ and $h = 0.45$ as in our experiment. Then, we must have $z_L < e$ and Period 2 proposals are the following: $x^2 = (e, h)$ after (N, Y) (R1 has voted N and R2 has voted Y), $x^2 = (e, e)$ after (Y, N) , and $x^2 = (e, e)$ after (N, N) . That is R1 will be offered one third

³⁸Beliefs are determined by Bayes' rule. Here, R1 is believed to be egalitarian in Period 2 with probability $\frac{\epsilon}{\epsilon + \frac{(1-\epsilon)}{2}} = \frac{2\epsilon}{1+\epsilon}$.

³⁹Proposing (e, e) can be shown to be dominated by proposing (e, h) .

of the pie in Period 2 in all of the cases. R1's price, given that R2 votes N if egalitarian and Y if rational (i.e., R2's voting Y probability vector is $(0, 1, 1)$), thus is⁴⁰

$$z_L^u(0, 1, 1) = (1 - \delta)l + \delta e \approx \begin{cases} 0.139 & \delta = 1/6 \text{ and } \epsilon = 1/2, \\ 0.294 & \delta = 5/6 \text{ and } \epsilon = 1/2. \end{cases}$$

2.B.3 Majority rule: A Period 1 MWC

Let us take a look at Period 1 MWCs under majority rule. R2 is excluded, i.e., $x^1 = (x_1^1, 0)$. So the question that remains is what P needs to offer to R1 in order to reach an agreement. To address this question, let us calculate R1's prices (for high and low-type responders).

The high type's price The following analysis assumes that P proposes $x^1 = (z_H, 0)$. Note that we only reach Period 2 if both responders have voted N on $x^1 = (z_H, 0)$. P will not have learned anything about R2. R1, on the other hand, only votes N if he is of the egalitarian type. Thus, in Period 2 each player knows her/his own type and the beliefs about the other players' types are given by $\omega = (0, (1, \frac{1}{2}), (\epsilon, \frac{1}{2}))$.

In Period 2, P either makes the equal proposal so that R1 votes Y for sure or builds a MWC with R2:⁴¹ $x^2 = \begin{cases} (0, h) & \epsilon < \frac{2e-h}{1-h} \approx 0.39, \\ (e, e) & \text{otherwise.} \end{cases}$ As we assumed $\epsilon = 1/2$, the EU of a high type R1 after reaching Period 2 is $u_1^2 = \frac{1+\epsilon}{2}e + \frac{1-\epsilon}{2}h$.⁴² The Period 1 price of a high type R1 thus amounts to (given that R2's voting Y probability is zero if being of the egalitarian type, if being rational and low, and if being rational and high):

$$z_H(0, 0, 0) = (1 - \delta)h + \delta \left(\frac{1+\epsilon}{2}e + \frac{1-\epsilon}{2}h \right) \approx \begin{cases} 0.435 & \delta = 1/6 \text{ and } \epsilon = 1/2, \\ 0.377 & \delta = 5/6 \text{ and } \epsilon = 1/2. \end{cases}$$

⁴⁰Note that this is indeed smaller than e and thus such price exists on the equilibrium path.

⁴¹The equal proposal gives P a utility of $1 - 2e$. The MWC leads to an EU of $(1 - \epsilon)(1 - h)$.

⁴²R2 votes N on the equal proposal only if he is rational and high (i.e., with probability $\frac{1-\epsilon}{2}$).

The low type's price The following analysis assumes that P proposes $x^1 = (z_L, 0)$. When Period 2 is reached, P will again not have learned anything about R2, as all types vote N on such a proposal. R1, on the other hand, either must be of the egalitarian type or of the rational high type. Beliefs are determined by Bayes' Rule and amount to $\omega = \left(0, \left(\frac{2\epsilon}{1+\epsilon}, 1\right), \left(\epsilon, \frac{1}{2}\right)\right)$.

In Period 2, P either makes the equal proposal so that R1 votes Y if being of the egalitarian type or forms a MWC with R2:⁴³ $x^2 = \begin{cases} (0, h) & h < 1 - \frac{1+\epsilon-\epsilon^2}{2(1-\epsilon^2)e}, \\ (e, e) & \text{otherwise.} \end{cases}$ Note that

for $\epsilon = 1/2$, $1 - \frac{1+\epsilon-\epsilon^2}{2(1-\epsilon^2)e} = \frac{13}{18} > h$ and thus P makes the equal proposal in Period 2. So the EU of a low type R1 after reaching Period 2 is $u_1^2 = e$. Thus, the Period 1 price of a low type R1 (given $\mu_2 = (0, 0, 0)$) thus amounts to

$$z_L(0, 0, 0) = (1 - \delta)l + \delta e \approx \begin{cases} 0.139 & \delta = 1/6 \text{ and } \epsilon = 1/2, \\ 0.294 & \delta = 5/6 \text{ and } \epsilon = 1/2. \end{cases}$$

⁴³The equal proposal passes in all cases but the one where both responders are rational and of the high type, leading to an EU for P of $(1 - (1 - \frac{2\epsilon}{1+\epsilon})\frac{1-\epsilon}{2})(1 - 2e)$. The MWC leads to an EU for P of $(1 - \epsilon)(1 - h)$.

Chapter 3

The “German Vote” and its consequences: (Un)reliable parties in multilateral bargaining under private information

Abstract

This paper theoretically investigates the strategic implications of varying *reliability* of bargaining partners under unanimous and non-unanimous voting. Three players (one proposer, two responders) bargain over the distribution of a pie. One responder has private information about his valuation of finding an agreement, implying signaling values that differ substantially between voting rules and are affected by the other responder’s reliability. Under unanimity rule, the responder with private information benefits from voting “no” because this signals that he requires a larger compensation in a future period. In contrast, under majority rule, voting “no” is unattractive due to the *fear of being excluded* from a future coalition. Under both voting rules, one responder becoming less reliable negatively affects the other responder’s willingness to vote “yes”, making efficient agreements increasingly difficult to achieve. The presence of unreliable parties can under majority rule lead to more parties being included in the winning coalition, as demonstrated by an extension of the model.

JEL codes: C78; D72; P48

Keywords: bargaining; voting; majority; unanimity; unreliability; private information

3.1 Introduction

“A German abstention during the vote on the EU supply chains law would send a terrible political message [...] and it would jeopardise Germany’s credibility — after all, German political leaders [...] have previously agreed that the EU supply chain law should be adopted, have actively engaged in negotiations, and shaped the most recent draft. There is also a risk that if Germany abstains, other countries will reconsider their position and withdraw their support, creating a domino effect.” (Human Rights Watch (2024))

Lately, the “German Vote” has become a term being discussed extensively at the EU Council in Brussels. Germany twice halted the introduction of a new law in a last minute blockade after having signalled being in favor of the new law in the months before. Such line of action is highly unusual and not well-respected in Brussels. Still, bargaining partners becoming increasingly unreliable appears to be a phenomenon prevalent around the world, be it the US with the possible return of Donald Trump into the White House, authoritarian states with unpredictable leaders, or, as mentioned above, Germany in the EU Council due to dissent between domestic ruling parties. More generally, any bargaining partner facing domestic elections tends to be somewhat unreliable, as a new government might have completely different views on the discussed issues.

This paper aims at modeling the respective consequences of having unreliable bargaining partners under the application of both unanimity and simple majority voting rules. Suppose France (the Proposer) plans the introduction of a new law at the EU level and therefore needs to convince the other states, say Germany and Italy (the responders), to vote yes. While France benefits from the introduction of the new law by one unit, the other states have private information about their valuation of the law. As I will demonstrate in a first step, a responder under unanimity rule can signal their dislike for the agreement by voting No, thereby indicating that they require substantial compensation to be convinced to vote yes. In contrast, under majority rule, signaling to dislike agreement by a No-vote leads to an increased risk of being excluded from a future coalition. Hence responders be-

come expensive under unanimity rule whereas an agreement is much easier to be reached under majority voting. Comparing the effects under various voting rules is crucial because the voting rules applied in the European Council vary across different policy areas.¹

I focus on the interaction between the Proposer and one of the responders (R1, say Italy), while assuming that the second responder (R2, say Germany) follows an exogenously fixed voting rule which varies in its “reliability”. Specifically, I assume that a fully “reliable” R2 votes yes with certainty whenever he is offered more than a certain exogenously fixed share c . In contrast, an “unreliable” R2 votes no with some probability p even when offered more than c . Under unanimity rule, this resembles the bilateral bargaining situation as in Schnedler and Vanberg (2014). Private information about one’s valuation of agreement leads to their idea of “playing hard to get”: Sophisticated players act as if they dislike a task in order to be compensated for it in the future.

This perfectly corresponds to the so-called *positive signaling value from voting No* in my model. By voting yes, responders, similarly, signal that they are “easy to get” (i.e., “cheap”). Italy must fear such *negative signaling value from voting yes* only in case a yes-vote does not secure immediate agreement with certainty. This is indeed the case when Germany is an unreliable bargaining partner who might vote no even though being offered the claimed share of c . As a result, a yes-vote becomes less attractive for Italy and finding an agreement gets more unlikely due to the unreliability of others.

Under majority rule, the *fear of being excluded* is predominant. This reduces the responders’ incentives to act “tough” compared to unanimity rule (see Buchanan and Tullock (1965)). The knowledge that after Italy voting No, France will build a coalition with Germany, makes Italy very “cheap”. Though, given that Germany has an established reputation as an unreliable partner, such *fear of being excluded* shrinks. That is, Germany’s unreliability makes Italy, similarly as under unanimity rule (though the underlying reasoning differs), less willing to vote yes and an agreement harder to achieve. Consequently,

¹At the EU Council, there is an ongoing debate whether to apply the “qualified majority rule”, instead of unanimity rule, more often (see for instance Schuette (2019)).

under both voting rules, *a party's unreliability makes others more reluctant to vote yes and thus more "expensive"*.

In most cases of interest, take for instance the EU Council or EU Parliament, the bargaining parties sit together and *simultaneously* vote about a proposed issue. There, parties do not observe others' votes before going to the ballot themselves but have formed beliefs about the others' voting intentions. These beliefs are based on the proposal and what has happened before the day of the vote, when the actual bargaining takes place. Parties talk to each other, try to form coalitions, and secure yes-votes. This, I assume to happen *sequentially*. That is, the Proposer (France) approaches the responders (Germany and Italy) one after another, while previous approaches are disclosed. So when facing an offer, responders announce their voting intention publicly. Hence the responder that is approached next is aware of all the responders that have been approached before, of the offers they have received, and of their announced voting decisions. The binding vote will then take place at the end of a period. In case all parties are reliable, they therefore vote exactly as they have announced. So, unreliability means that a party announces a yes-vote during the bargaining phase but then, with a positive probability, still ends up voting No.

In a world where fully reliable bargaining partners seem to become increasingly rare, understanding the bargaining process with unreliable players is essential. In the first part of the paper, I discuss the differences of unanimous and non-unanimous voting under private information with reliable players. Here, I will especially focus on players' signaling incentives which play an essential role in the underlying reasoning of the impact of unreliability. In a second step, I then try to shed some light on the consequences of others being unreliable under the two voting rules.

I start by reviewing the existing literature. The model is introduced in more detail in Section 3.3. The subsequent sections proceed to address the model assuming that responders are reliable (Section 3.4) and unreliable (Section 3.5), respectively. Section 3.6 provides a review of the primary findings, followed by some further insights and extensions

discussed in Section 3.7. Finally, Section 3.8 concludes.

3.2 Literature

This paper aligns with the broader literature on q -majority rules in multilateral bargaining games with complete information. Specifically, it intersects with models introducing heterogeneity regarding individual players' willingness to agree. For instance, in the classic Baron-Ferejohn bargaining game (Baron and Ferejohn (1989)), complete information is paired with varying discount factors among players. A higher discount factor implies a larger “price” for a player’s support. Whereas being expensive is a good thing under unanimity voting, Miller et al. (2018) show that it might be a disadvantage under majority voting, as expensive players risk exclusion from winning coalitions. These findings suggest that when heterogeneity stems from private information, players may prefer to signal toughness (e.g., through lower valuations for having an agreement) under unanimity rule, but not necessarily under non-unanimous voting.

The literature on multilateral bargaining with private information remains limited. Tsai and Yang (2010b) investigate a Baron-Ferejohn game with private information about discount factors, revealing equilibria involving delay and oversized coalitions under majority rule. Piazzolo and Vanberg (2024a) examine a model with privately known disagreement values, examining the distinct signaling incentives associated with different voting rules. In their examination of a three-player, two-period game with two different player types, they demonstrate that the “cheap” type may have an incentive to mimic the behavior of the “expensive” one under unanimity rule. Conversely, under majority rule, the dynamic may shift, with the “expensive” type attempting to appear as a “cheap” one.

Similar patterns emerge in the literature on reputational bargaining. Abreu and Gul (2000) analyze a bilateral bargaining game where players may be “obstinate” types committed to claiming a fixed share of the pie. They illustrate how the presence of such types incentivizes “sophisticated” types to imitate them, i.e., to adopt a tough stance, and thus

possibly leading to inefficient delays. Ma (2023) extends this concept to a multilateral majoritarian bargaining game, underscoring how the *threat of exclusion* under majority rule dampens incentives to act tough.

My work builds upon and extends this line of reasoning in two key ways. Firstly, it introduces a model that allows for a focused examination of the behavior of individual players, thereby enabling a detailed discussion of their signaling incentives, confirming the results of Piazzolo and Vanberg (2024a).² Secondly, it seeks to illuminate the implications of bargaining parties becoming increasingly difficult to rely on. Lewicki and Polin (2013) discuss the general role of trust in negotiations and differentiates between short and long-term consequences of having established a reputation of unreliability. In the short term, deceptive tactics may yield benefits (as noted in Schweitzer and Croson (1999)), while in the long term, opponents are far less inclined to seek a coalition with an unreliable party. The latter is, for instance, confirmed by Boles et al. (2000). They conduct an experiment on the consequences of deceptive behavior in a proposer-responder framework and find that players express a diminished desire to interact in forthcoming periods with players that were assessed as untrustworthy. To the best of my knowledge, this paper represents the first attempt to theoretically explore the effects of a party's reputation for unreliability on other parties' voting behavior within a multilateral bargaining framework with private information.

3.3 Model

Three players bargain over the distribution of a pie of size one. There is one fixed proposer (P, she) and two responders (R1 and R2, he). The game lasts at most two periods. Each

²In comparison to Piazzolo and Vanberg (2024a), the model of the present paper brings two main benefits. Firstly, it manages to find the same results in a simplified analysis without having to consider mixed strategies. Secondly, it allows to isolate effects of interest and, most importantly, discusses the consequences of the presence of unreliability.

Period $t \in \{1, 2\}$ consists of two sub-periods³ and is of the same structure: First, P decides which of the responders to approach first. Then, in sub-period ta ($1a$ or $2a$), P makes a publicly observable and (weakly) positive offer to the responder, she decided to approach first. The respective responder announces (also publicly observable) his voting intention, which can either be a “Yes” (Y) or a “No” (N) vote. In sub-period tb , P makes an offer to the other responder, who subsequently announces his voting intention (Y or N). At the end of a period the decisive ballot takes place. P proposes to all responders who announced a Y-vote the offer she has made in the respective sub-period to the respective responder. Responders who announced a N-vote face a zero-offer. R1 then votes as announced. In contrast, the *unreliable* R2 might, in Period 1, vote N even after having announced a Y-vote, resulting in the following definition.

Definition 3. A party is *unreliable* if there is a probability $p \in (0, \frac{1}{2})$ with that it, in Period 1, votes “No” after having announced a “Yes”-vote. A party is *reliable* if it always votes as it has announced.

Note that it is assumed that p is exogenously given. A conceivable extension of the model might treat p as a strategic choice.⁴ However, our main interest lies in the effect of the (level of) unreliability of R2 on R1’s voting behavior.

P’s proposal at the end of Period $t \in \{1, 2\}$ is of the form $x^t = (x_1^t, x_2^t)$. There is an agreement if, in the decisive ballot, at least q responders vote Y. R1 then obtains his offered share x_1^t in addition to an exogenously given valuation of agreement v . P gets the remainder of the pie $1 - x_1^t - x_2^t$. R2, in contrast, is assumed to be of a non-strategic “robot” type that announces a Y-vote in Period t if and only if he is offered at least some fixed and publicly known share $c \in (0, 1)$. If there is no agreement in Period 1, there is

³Here, the actual “bargaining” takes place. Parties discuss and work on the law that is to be voted on. There, parties can signal/announce their intended voting decision and P discloses the concessions she is willing to make.

⁴In case the level of unreliability depends on the received offer, there might be room for “strategically” making use of being perceived as unreliable. This might be interesting to explore in future research and will be discussed in more detail below.

3. Multilateral bargaining with private information: (Un)reliability

an immediate breakdown with probability $1 - \delta$. With the continuation probability δ we go into a second round of bargaining, where both responders are reliable. If there is no agreement in Period 2, there is an immediate breakdown with probability 1. In case of a breakdown, all three players have a payoff of zero. Beliefs are formed via Bayes' Rule. See Table 3.1 for a summary of the bargaining procedure.

Period t	Player	Action	Decision process
Before ta	P	Approach Ri first ($i \in \{0, 1\}$)	max utility
ta	P	Offers x_i to Ri	max utility
	Ri	Announce Y or N-vote	max utility (for R1)
tb	P	Offers x_j to Rj	max utility
	Rj	Announce Y or N-vote	Y if at least c (for R2)
Ballot (after tb)	P = <i>France</i> R1 = <i>Italy</i> R2 = <i>Germany</i>	Propose $x^t = (x_1^t, x_2^t)$ Vote Y or N Vote Y or N	$x_k^t = x_k$ if Rk announced Y as announced switch from Y to N with prob p

Table 3.1: The bargaining process

In the following, I compare majority ($q = 1$) with unanimity voting ($q = 2$). In the course of this, the main focus will lie in the interaction between P and R1. R1's valuation of agreement, denoted as v , is of private information to him. This parameter follows a uniform distribution on the interval $[-1, 1]$, as known to all players. Agreement is welfare-maximizing for certain combinations of v and c (specifically, when $1 + v - c > 0$), whereas breakdown is welfare-optimal for other combinations (when $1 + v - c < 0$).

Equilibrium concept In this game, R1's strategy must specify his voting announcement for each of his agreement valuations, referred to as types, for every potential proposal and history. A history is considered empty during sub-period $1a$. In $1b$, it includes the offer and the announced vote from sub-period $1a$. During sub-period $2a$ (and $2b$), it encompasses all preceding offers and announced votes, along with the responders' votes in the decisive ballot at the end of Period 1. The strategy of the non-strategic type R2 is predetermined (as detailed earlier) and thus can be disregarded. P's strategy entails determining the respon-

der she approaches first in Period 1 and, for each possible historical sequence, formulating Period 1 and Period 2 proposals, as well as determining the responder she approaches first in Period 2. An equilibrium strategy necessitates maximizing the respective player's expected payoff at every point of the game (Perfect Bayesian equilibrium). It's worth noting that R1's expected utility from voting Y increases continuously with his valuation of finding an agreement v . Consequently, R1's strategy can be simplified: In each Period, he will opt for a Y-vote on a given offer whenever his valuation of agreement exceeds a certain *cutoff*.⁵

Cutoff type Hence, whenever R1 is approached in Period 1, there will be a cutoff value $\hat{v}$ such that R1 votes Y if $v \geq \hat{v}$ and N if $v < \hat{v}$. The type of R1 with a valuation of agreement of $v = \hat{v}$ will be called the *cutoff type*. Such a type is indifferent between voting Y and N. There, the probability of $v = \hat{v}$ is zero, i.e., we can, w.l.o.g., assume that such a responder votes Y. The value of $\hat{v}$ will depend on the offer $x^1 = (x_1^1, x_2^1)$, where $x_1^1 = x$ and $x_2^1 \in \{0, c\}$ as well as on the sequence with that responders are approached.⁶ The voting Y probability of R1 from P's perspective is $\frac{1-\hat{v}}{2}$.⁷

Employing backward induction, I initially examine the behavior in Period 2. There, R1 opts to vote Y on an offer x if it yields “immediate” positive utility, i.e., when $x + v \geq 0$. P's expected utility depends on the belief concerning R1's valuation of agreement and thus on the cutoff type. After a Period 1 N-vote of R1, P believes R1's valuation of agreement to be uniformly distributed on $[-1, \hat{v}]$. If R1 voted Y in Period 1, then v is believed to be

⁵The fundamental difference to the model of Piazzolo and Vanberg (2024a) is that in their model, there are only two types of responders: Low types mimic high types' behavior, which is especially beneficial if only a few low types do so. Consequently, there is a range of offers where low types would want to mimic high ones if P expects a low type not to mimic, and low types do not want to mimic if P expects them to mimic. Hence, no pure-strategy equilibrium exists. In a mixed-strategy equilibrium, the proportion of low types that mimic, and thus the signaling value, can be adjusted depending on the offer. Conversely, in the model of the underlying paper, the cutoff type allows for the precise determination of the proportion of the responder's “types” that vote Y, eliminating the need for mixing.

⁶For simplicity, we drop the cutoff type's dependencies in the notation. We will see that on the equilibrium path, the cutoff type will essentially just depend on the offer x that R1 faces in Period 1.

⁷The voting Y probability of R2 is p if $x_2^1 \geq c$ and zero otherwise.

uniformly distributed on $[\hat{v}, 1]$. So by voting N in Period 1, a responder can signal that he is likely to have a relatively low valuation of finding an agreement and consequently it requires a large Period 2 compensation in order for him to vote Y.⁸ In Period 1, analyzing R1's voting behavior requires a more nuanced approach, contingent upon the sequence of responders, R2's expected behavior in Period 1 (including reliability), the continuation probability, and the specifics of the Period 1 offer. The cutoff type function $\hat{v}(x^1)$ captures most of these dependencies. P will consider this function when maximizing her expected utility over x^1 , guiding us toward the equilibrium proposal.

In the subsequent analysis, one main focus is on determining the cutoff types under the different setups. The equilibrium cutoff not only gives us the equilibrium proposal but also indicates R1's willingness to vote Y (thus providing us with a "price" for R1) and shows how this willingness is affected by certain parameters, such as the Period 1 offer or the reliability of R2. Consequently, the cutoff type serves as the key piece of information P requires when devising her optimal proposal. Simultaneously, providing the cutoff type offers us a comprehensive equilibrium strategy for R1. This is because the cutoff type perfectly describes R1's behavior in Period 1, while R1's actions in Period 2 follow a consistent pattern: Vote Y on an offer x whenever $x + v \geq 0$, and N otherwise.

Responder's price R1's Period 1 cutoff type is thereby perfectly correlated with his "price". A higher cutoff type indicates a greater likelihood of R1 voting N, thus rendering him expensive, or, in other words, leading to a higher "price". To avoid any confusion when discussing R1's "price" or whether R1 is considered cheap or expensive, the following definition is provided.

Definition 4. R1's Period 1 price $z(v)$ is defined as the lowest Period 1 offer that R1 is willing to vote Y on.

Examining R1's price is particularly insightful when comparing different situations of

⁸Note that such signaling only works if R1 expects his vote to be pivotal with a positive probability. It turns out that this is indeed true in all cases of interest.

interest, as it allows us to assess the impact of various parameters on R1's willingness to vote Y. Of particular interest is the effect of R2's unreliability on R1's price under the two voting rules. The following sections thus explore the consequences of the presence of an unreliable party under both majority and unanimity rule. To accomplish this, it is crucial to first understand the signaling incentives under both voting rules when parties are reliable (see Section 3.4). Subsequently, we are prepared to assess how unreliability impacts these signaling incentives (see Section 3.5).

3.4 Reliable parties ($p=0$)

This section assumes that R2's voting announcement can be fully trusted, i.e., $p = 0$. More specifically, R2 ends up voting Y whenever he is offered at least c (by assumption) and votes N, otherwise.

3.4.1 Majority rule

First, let us consider majority voting. Throughout both periods, P's offer to R2 will either be zero or c . When P offers c to R2, an immediate agreement is guaranteed since R2 is fully reliable. P strategically leverages the potential for an immediate and certain agreement to heighten R1's *fear of exclusion*. The *threat of exclusion* is most powerful when it looms within the same period,⁹ leading to the following Lemma.

Lemma 9. Under majority rule, P always approaches R1 first. In Period 2, R1 announces a Yes-vote on any (weakly) positive offer.

If R1 votes¹⁰ N in sub-period 2a, P forms a Minimum Winning Coalition (MWC)¹¹

⁹Recall that R2 is of a non-strategic type and *fear of exclusion* cannot make him more eager to vote Y. Hence P never approaches R2 first.

¹⁰For R1, and also R2 in case he is reliable, I can use the terms vote and announce a vote likewise. That is because the vote equals the announced vote.

¹¹A MWC is characterized by a voting outcome where exactly the necessary number of parties for an agreement to be reached vote Y. Specifically, under majority rule, one responder votes Y while the other votes N.

with R2 in sub-period 2b. R1 is aware that, independent of his voting decision, there will be an agreement. Consequently, P, in sub-period 2a, will make a zero-offer to R1 and R1 announces a Y-vote,¹² leading to a certain agreement.

Period 1 behavior is shaped by players' anticipations for Period 2 outcomes. P expects securing an agreement that allows her to retain the entire pie. Consequently, in sub-period 1b, P faces a trade-off: she must weigh the option of an immediate agreement, costing her c , against the hope for Period 2 to be reached, which happens with probability δ . The former is advantageous if R2 is cheap, while the latter is preferable if the likelihood of advancing to Period 2 is high.

The resolution of this trade-off dictates R1's behavior in sub-period 1a. So, in the following, let us differentiate between the following two cases.

Firstly, suppose that $c > 1 - \delta$. Then P makes a zero offer to R2 ("waits"). R1 anticipates this and therefore does not need to fear immediate exclusion. Consequently, a responder with a negative valuation of agreement can hope for a breakdown to occur (with probability $1 - \delta$). More specifically, R1 is indifferent between voting Y and N if $x + v = (1 - \delta)0 + \delta v$, i.e., if $v = \hat{v}$ with

$$\hat{v} = -\frac{x}{1 - \delta}, \text{ given } c > 1 - \delta.$$

Therefore, R1's cutoff type $\hat{v}(x)$ is negative. Thus, a responder with a positive valuation of agreement votes Y on all positive offers x (remember that R1 votes Y whenever $v \geq \hat{v}(x)$). Also, the cutoff value is decreasing in δ , i.e., R1 is more likely to vote Y the larger is the continuation probability. This trend stems from R1's apprehension about being forced to vote Y on a zero offer (similar to being excluded from a coalition), a concern that intensifies with δ .¹³

¹²W.l.o.g., it is assumed that responders vote/announce Y whenever being indifferent between a Y-vote and a N-vote.

¹³Here, P will choose x such that her expected utility $\frac{1+\frac{x}{1-\delta}}{2}(1-x) + \frac{1-\frac{x}{1-\delta}}{2}\delta$ is maximized. This leads to a negative offer (not feasible) and thus P chooses $x = 0$ in the optimum.

Secondly, suppose $c \leq 1 - \delta$. Then, P opts to secure R2's agreement in sub-period 1b. R1 thus faces a *fear of immediate exclusion* after announcing a N-vote. Analogous to Period 2, this prompts R1 to vote Y on every offer he faces, i.e.,

$$\hat{v} < -1, \text{ given } c \leq 1 - \delta.$$

Combining this with $\hat{v} < -x$ from above (i.e., for $c > 1 - \delta$) leads to the following observation.

Observation 1. Under majority rule and with reliable responders, R1 fears exclusion and is thus willing to vote Yes on offers that give him negative immediate utility: $\hat{v} < -x$.

The ensuing proposition presents an overview of the resulting equilibrium behavior and follows without further proof.

Proposition 5. *Under majority rule and with reliable responders, P approaches R1 first in both periods and proposes*

- to R1 in Period 1a
 - if $c \leq 1 - \delta$: $x = 0$. R1 announces a Yes-vote.
 - if $c > 1 - \delta$: $x = 0$. R1 announces a Yes-vote if $v \geq 0$.
- to R2 in Period 1b, after R1 announced a No-vote,
 - if $c \leq 1 - \delta$: $x_2^1 = c$. R2 announces a Yes-vote.
 - if $c > 1 - \delta$: $x_2^1 = 0$. R2 announces a No-vote.
- to R1 in Period 2a: $x_1^2 = 0$. R1 announces a Yes-vote.
- to R2 in Period 2b, after R1 announced a No-vote: $x_2^2 = c$. R2 announces a Yes-vote.

Hence P profits substantially from the given sequential structure of the game with reliable responders and majority rule being applied.¹⁴ She benefits most if δ and/or c is small. P benefiting from a low probability of advancing into a second period seems counterintuitive at first. However, a low δ intensifies R1's *fear of exclusion* because R1 must expect P to form a MWC with R2 in Period 1 already (the urgency of an immediate agreement for P decreases in δ). So announcing a N-vote becomes unattractive and thus R1 is very “cheap” (his Y-vote essentially comes for “free”).¹⁵

3.4.2 Unanimity rule

The main feature of unanimity voting is that no party must fear exclusion. Thus, R2 must be offered at least c for an agreement to be feasible. As a result, the sequence in which responders are approached is irrelevant because it is common knowledge that R2 is offered c and announces a Y-vote. Lemma 10 follows directly.

Lemma 10. Under unanimity rule, P offers c to R2 and is indifferent between approaching either responder first in both periods.

Period 2 will be reached only after R1 has voted N. Assuming that R1 follows a cutoff strategy, P expects R1's valuation of agreement to be uniformly distributed on $[-1, \hat{v}]$. P's optimal Period 2 proposal depends on R1's cutoff value and is given by

$$x_1^2 = \frac{1 - c - \hat{v}}{2}.$$

Note that x_1^2 is continuously decreasing in $\hat{v}$. The intuition is that the more types of R1 vote Y (smaller $\hat{v}$), the stronger is the signaling value from voting N and thus the larger is

¹⁴In a model with simultaneous voting, there would not be the (same) threat of being “immediately” excluded.

¹⁵Part of this reasoning comes from the assumption that breakdown cannot occur in between offers. A related and also reasonable model would have a breakdown probability following each sub-period, leading to a reduced *fear of “immediate” exclusion* for the responders. Interestingly, this would introduce a cost of forming the “wrong” coalition.

the offer made in Period 2. In Period 1, given an offer x , R1 is indifferent between voting Y and N if $v = \hat{v}$, with the cutoff value

$$\hat{v} = \frac{\delta(1-c) - 2x}{2-\delta}.$$

Consequently, a Period 1 N-vote leads to an increased offer in Period 2: The Period 2 offer amounts $x_1^2 = \frac{(1-\delta)(1-c)+x}{2-\delta}$ (when plugging in $\hat{v}$), which is increasing in x and also larger than x .¹⁶ As a result, R1 is willing to vote N on Period 1 offers that seem profitable at first sight. More specifically, the cutoff type's immediate utility from acceptance would be $x + \hat{v} = \frac{\delta(1-c-x)}{2-\delta}$ and thus is always positive.¹⁷ Hence all types of R1 with $v \in [0, \hat{v}]$ vote N in Period 1 even though they value agreement positively, as stated by the following observation.

Observation 2. Under unanimity rule and with reliable responders, R1 faces, in Period 1, a *positive signaling value from voting No* and thus might vote No on offers that give him positive immediate utility: $\hat{v} > -x$.

Consequently, Period 1 allows R1 to make the following gamble: Vote N, thereby signal that he must be compensated heavily for a Y-vote (i.e., that he has a low valuation of agreement), and hope to receive a larger share in Period 2. There, the respective *positive signaling value from voting N* increases with δ , rendering R1 more inclined to vote N (i.e., more costly) in Period 1 (as can be seen by $\frac{\partial \hat{v}}{\partial \delta} > 0$). That is because responders can only benefit from signaling if a second round of bargaining is reached.

In a last step, P's optimal Period 1 proposal is to be computed. This is presented in the proof of the following proposition which summarizes the equilibrium behavior.

Proposition 6. *Under unanimity rule and with reliable responders, P is indifferent between approaching either responder first in both periods and offers c to R2. To R1, she proposes*

¹⁶That is because $x + c < 1$ must hold.

¹⁷ $1 - c - x \geq 0$ holds because R2 is offered c and $x + c \leq 1$ must hold.

- in Period 1: $x = \max \{0, \tilde{x}(c, \delta)\}$, where $\tilde{x}(c, \delta)$ is decreasing in c . R1 votes Yes if he values agreement sufficiently ($v \geq \hat{v}$).
- in Period 2, after R1 has voted No: $x_1^2 > x$, where x_1^2 is increasing in the Period 1 offer x .¹⁸ R1 votes Yes iff $x_1^2 + v \geq 0$.

Proof. See the Appendix for the proof of this Proposition and also for the above discussed derivations of x_1^2 and $\hat{v}$. □

Note that the impact of the continuation probability δ on the optimal Period 1 proposal is ambiguous. That is because a reduced Period 1 propensity of R1 to vote Y, which can be caused by a larger δ , induces opposing effects. On one hand, P seeks to take countermeasures against the reduced likelihood of R1 to vote Y and thereby must augment her offer. On the other hand, each type of R1, due to the increased *positive signaling value from voting N*, demands a larger offer. This diminishes the incremental value of an increased offer and potentially leads to a reduction in the optimal offer.

3.5 Unreliable parties ($p > 0$)

In this section, R2 is assumed to be unreliable, i.e., $p > 0$. In Period 1, R2 might now vote N even after having announced a Y-vote (see Definition 3). In the following, the equilibrium behavior under both voting rules and with an unreliable R2 will be analyzed.

3.5.1 Majority rule

Recall that R2 is only unreliable in Period 1. Hence, in Period 2, nothing has changed compared to the analysis in Section 3.4.1. Specifically, Lemma 9 remains valid: R1 is approached first in both periods, and in Period 2, R1 votes Y on any offer. Consequently,

¹⁸The Period 1 offer is $\tilde{x}(c, \delta) = \frac{\delta(1-\delta) - (2-\delta - \frac{\delta^2}{2})c}{4-3\delta}$. The increased Period 2 offer, after R1 has voted N in Period 1, is increasing in the Period 1 offer x and amounts to $x_1^2(x) = \frac{(1-\delta)(1-c)+x}{2-\delta}$.

P retains the entire pie for herself in Period 2. In sub-period 1*b*, P again - like in the “reliable” case - faces the trade-off of either seeking an immediate agreement with R2 or deferring negotiations to Period 2.

The resolution of this trade-off will be again crucial for R1’s Period 1 behavior. Therefore, we must differentiate between the following two cases, exactly like in the “reliable” case above.

Firstly, suppose $c > 1 - \delta$, i.e., that R2 is quite costly. As a consequence, P makes a zero-offer to R2 in sub-period 1*b*. In sub-period 1*a*, R1 anticipates this. Hence there is no *fear of immediate exclusion* and R1’s cutoff type is the same as in the reliable case

$$\hat{v} = -\frac{x}{(1 - \delta)}, \text{ given } c > 1 - \delta.$$

Secondly, suppose that $c \leq 1 - \delta$. Then, P tries to reach an immediate agreement in sub-period 1*b*. Consequently, P proposes c to R2, who then announces a Y-vote. However, in contrast to the reliable case, there is a chance that R2 might still vote N (with probability p). Hence, in sub-period 1*a*, R1’s concern about a Period 1 exclusion, and thus his cutoff type, hinges on R2’s unreliability p :

$$\hat{v} = -\frac{x}{(1 - \delta)p}, \text{ given } c \leq 1 - \delta.$$

If $x \geq (1 - \delta)p$, then $\hat{v} \leq -1$. In words, this means that if the offer is large enough, all types of R1 vote Y in Period 1. As discussed before, the same holds in case R2 is very reliable: Recall that $p = 0$ leads to $\hat{v} < -1$. Increasing R2’s unreliability p leads to a reduced threat of Period 1 exclusion for R1. Thus, R1 becomes more willing to vote N.¹⁹ The same we can observe by looking at R1’s Period 1 price:

Observation 3. Suppose majority rule is applied, $c \leq 1 - \delta$, R2 is unreliable, and R1

¹⁹Also note that if δ is large, breakdown becomes unlikely, and thus R1 is again willing to vote Y on small offers. That is because reaching Period 2 is bad for R1 as then he will have to vote Y on the smallest possible offer (zero).

3. Multilateral bargaining with private information: (Un)reliability

values agreement negatively $v < 0$.²⁰ Then R1's Period 1 price $z(v) = -(1 - \delta)pv$ is increasing in R2's level of unreliability p .

Recall that we defined the price of R1 with a valuation of agreement v as the offer, where there is a continuation equilibrium with R1 being indifferent between voting Y and N in Period 1 (see Definition 4). So, discussing R1's cutoff value is equivalent to discussing his price. Note that the above observation only holds if R2 is not too expensive and $v < 0$. In the remaining cases, the relationship between R2's unreliability and R1's price is the following: If R2 is expensive, his price will be independent of p . If R1 values agreement positively and R2 is cheap, then R1 votes Y on all offers, i.e., his "price" is zero and thus also independent of p .

Solving P's maximization problems in both cases (for small c and large c , respectively) leads to Proposition 7.

Proposition 7. *Under majority rule and with an unreliable R2, P approaches R1 first in both periods and proposes*

- *to R1 in Period 1a*
 - *if $c \leq 1 - \delta$: $x = \tilde{x}(c, \delta, p) > 0$.²¹ R1 votes Yes if $v \geq -\frac{\tilde{x}(c, \delta, p)}{(1-\delta)p}$.*
 - *if $c > 1 - \delta$: $x = 0$. R1 votes Yes if $v \geq 0$.*
- *to R2 in Period 1b, after R1 announced a No-vote,*
 - *if $c \leq 1 - \delta$: $x_2^1 = c$. R2 announces a Yes-vote.*
 - *if $c > 1 - \delta$: $x_2^1 = 0$. R2 announces a No-vote.*
- *to R1 in Period 2a: $x_1^2 = 0$. R1 announces a Yes-vote.*
- *to R2 in Period 2b, after R1 announced a No-vote: $x_2^2 = c$. R2 announces a Yes-vote.*

²⁰Note that R1's price is of our main interest if he values agreement negatively. Otherwise, he will just vote Y on any offer.

²¹ $\tilde{x}(c, \delta, p) = \min\{\frac{(1-p)c}{2}, (1-\delta)p\}$.

Proof. See Appendix. □

If R1 values agreement positively, he votes Y in Period 1 with certainty, resulting in an immediate agreement. If R1 values agreement negatively, his Period 1 behavior hinges on his *fear of exclusion* or, more specifically, on his hope for not finding an agreement (i.e., a breakdown). As the likelihood of a breakdown increases, R1's willingness to vote Y decreases. Thus, R2's unreliability p , similar to the breakdown probability $1 - \delta$, raises R1's price and may prompt a positive Period 1 offer.

3.5.2 Unanimity rule

If unanimity rule is applied, P can only secure an agreement if she offers c to R2. R2 will then announce a Y-vote but still ends up voting N with probability p . This outcome remains consistent regardless of the order in which responders are approached, meaning Lemma 10 remains valid.

Moreover, the process driving the players' equilibrium behavior remains largely analogous to the reliable case discussed above. In Period 1, R1 once again confronts a trade-off: either opt for a N-vote in the hope for an increased Period 2 offer, or opt for a Y-vote, thereby pursuing immediate agreement. The pivotal distinction now is that a Y-vote no longer ensures immediate agreement with certainty, due to R2's unreliability. As a consequence, we must not only discuss the Period 2 proposal after R1 has voted N but also after R1 has voted Y. After such a Y-vote, P believes R1's valuation of agreement to lie in the interval of $[\hat{v}, 1]$. She will then end up making a zero offer if Period 2 is reached (see proof of Proposition 8 for more details). The Period 2 offers are therefore given by

$$x_1^2 = \begin{cases} \frac{1-c-\hat{v}}{2} & \text{after Period 1 N-vote,} \\ 0 & \text{after Period 1 Y-vote.} \end{cases}$$

Thus, P and R1 must not only take into account the signaling value from voting N but

also the one from voting Y. Here, a prior Y-vote signals to P that R1 is likely to value agreement positively, leading to a smaller Period 2 offer than a Period 1 N-vote and thus to the following Observation.

Observation 4. Suppose unanimity rule is applied and R2 is unreliable. Then, in Period 1, R1 faces a *positive signaling value from voting No* and a *negative signaling value from voting Yes*.

Thus, a Y-vote carries the risk of receiving a low offer in a subsequent period. Consequently, R2's unreliability decreases R1's willingness to vote Y, resulting in an increased Period 1 price - as described by the following Observation:

Observation 5. Suppose unanimity rule is applied, R2 is unreliable, and $v \in [c - 1, 1 - c]$. Then R1's Period 1 price $z(v) = -(1 - \delta)v + \frac{\delta(1-c-v)}{2(1-p)}$ is increasing in R2's level of unreliability p .²²

Proof. See Lemma 15 for the derivation of R1's price. $\frac{\partial z(v)}{\partial p} = \frac{(1-c-v)\delta}{2(1-p)^2}$ is positive if $v < 1 - c$. If $v > 1 - c$, R1 votes Y with certainty (price of zero). If $v < c - 1$, R1 votes N with certainty (price larger than one). $\square$

Recall that R1's Period 1 price comes from the same constraint as his cutoff type. A higher cutoff type implies that fewer types of R1 are willing to vote Y in Period 1, resulting in a higher Period 1 price. In this case, the equilibrium cutoff type is given by²³

$$\hat{v} = \frac{\delta(1 - c) - 2(1 - p)x}{2(1 - p)(1 - \delta) + \delta}.$$

Similar to R1's price, this cutoff value is increasing with R2's unreliability p .

²²The here discussed price $z(v)$ is the on-equilibrium path price, where $\hat{v} \geq 0$. If $\hat{v} < 0$, then R1's price would amount $z(v) = -v + \frac{\delta(1-c+v)}{2(1-p)}$. However, making an offer that leads to $\hat{v} < 0$ is dominated for P. For more details see the Appendix or the next footnote.

²³Note that $\hat{v} = \frac{\delta(1-c)-2(1-p)x}{2(1-p)-\delta}$ if $\hat{v} < 0$. However, P's equilibrium proposal is only consistent with $\hat{v} \geq 0$ (in other words: there is no equilibrium with $\hat{v} < 0$), where $\hat{v} = \frac{\delta(1-c)-2(1-p)x}{2(1-p)(1-\delta)+\delta}$. So the latter $\hat{v}$ is the one we concentrate on.

Proposition 8 now outlines the equilibrium behavior, derived from solving P's maximization problem(s) while taking R1's respective cutoff type into account.

Proposition 8. *Under unanimity rule and with an unreliable R2, P is indifferent between approaching either responder first in both periods and offers c to R2. To R1, she proposes*

- *in Period 1: $x = \max\{0, \tilde{x}(c, \delta, p)\}$, where $\tilde{x}(c, \delta, p)$ is decreasing in c . R1 votes Yes if $v \geq \hat{v}$.*
- *in Period 2, after R1 announced a Yes-vote in Period 1: $x_1^2 = 0$. R1 votes Yes if $v \geq 0$.*
- *in Period 2, after R1 announced a No-vote in Period 1: $x_1^2 > x$.²⁴ R1 votes Yes if $x_1^2 + v \geq 0$.*

Proof. See Appendix. □

As noted above, the effect of R2's unreliability on R1's price is clearly identified and positive (see Observation 5). In contrast, the impact on P's Period 1 offer is ambiguous. This ambiguity arises because a higher price for R1 does not necessarily result in a larger offer from P, although it might. Further insights on the effect of R2's unreliability are discussed in the subsequent section.

3.6 A comparison of the voting rules: Main results

In the following, I discuss the differences between the two voting rules, particularly focusing on the distinct strategic considerations R1 takes into account. Additionally, I (re-)state the primary findings of the previous analyses. Under unanimity rule, the emphasis is on understanding R1's behavior for intermediate values of v . If R1 highly values reaching an

²⁴The optimal Period 1 offer is $x = \max\{0, \tilde{x}(c, \delta, p)\}$, where $\tilde{x}(c, \delta, p) = \frac{(1-\delta)\delta - (1-\delta)c(2+\delta-2p+2p\delta) - \frac{\delta^2}{2(1-p)}c}{4(1-p)(1-\delta)+\delta}$. The optimal Period 2 offer, after R1 has voted N in Period 1, is $x_1^2 = \frac{1-c-\hat{v}}{2}$.

agreement, he will vote Y regardless of the risks, as the potential breakdown is not worth the gamble. Conversely, if R1 strongly opposes the agreement, he will consistently vote N, knowing that no agreement will materialize without his consent. Although the following results apply to all values of v , our focus when discussing the main results narrows to the more insightful range $v \in (c - 1, 1 - c)$.²⁵

First, let us compare the responders' inclination to vote Y (i.e., R1's prices) and the associated likelihood of breakdown between majority and unanimity rule. The disparities primarily stem from the *fear of exclusion*²⁶ under majority rule and the *positive signaling value from voting N* under unanimity rule. These factors, influenced in part by private information,²⁷ exert opposing effects on R1's willingness to vote Y, i.e., on his Period 1 price: Under majority rule, R1's price is $z(v) = -(1 - \delta)pv$ if c is offered to R2 in sub-period 1b (i.e., if $c \leq 1 - \delta$) and $z(v) = -(1 - \delta)v$ if R2 is offered zero in 1b (i.e., if $c > 1 - \delta$). Under unanimity rule, R1's price is $z(v) = -(1 - \delta)v + \frac{\delta(1 - c - v)}{2(1 - p)}$. This leads to the following two results (for more details, see 3.B).

Result 1. When facing a Period 1 offer x , R1 is (weakly) more willing to vote Yes if majority rule is applied than if unanimity rule is applied.

Finding an agreement under unanimity rule is - by construction - harder to achieve than under majority rule: By definition more players must be convinced to agree if unanimity is required. In addition, each responder individually is less willing to vote Y under unanimity than under majority rule (see Result 1). Thus, Result 2 is not surprising.

Result 2. The probability of breakdown is lower under majority rule than under unanimity rule.

²⁵Note that $v > c - 1$ means that having an agreement is efficient. When discussing welfare, we will also take a look at $v < c - 1$.

²⁶To be more precise, in our setup the *fear of exclusion* is the fear of ending up in an agreement which results in a negative utility (i.e., where $x + v < 0$). This can either be the case when R1 is excluded from the coalition or when R1 is pressured to vote Y on small offers that lead to such negative utility. The latter is always the case when Period 2 is reached under majority voting.

²⁷There is no room for any signaling under complete information. Consequently, the differences between the two voting rules are larger in the private information environment than in the full information one.

It's noteworthy that if R2 is fully reliable and unanimity rule is applied, there is a breakdown in half of the cases independent of the parameter values - hence, even when δ is large and the cost of R2 (c) is low. In contrast, under majority rule, there might be an agreement with certainty in such cases. This outcome is due to R1 becoming prohibitively expensive under unanimity rule. When R1 perceives a diminished risk of breakdown (with a large δ), he is more inclined to take the risk to vote N in Period 1 with hopes of securing a larger share in Period 2 - a scenario characterized by a substantial *positive signaling value from voting N*. Similarly, if R2's cost is low, R1 can anticipate a larger share in Period 2, incentivizing him to vote N in Period 1. At the same time, he faces a larger Period 1 offer, ultimately leading to a stable probability of agreement.

While the results 1 and 2 hold independent of R2's reliability, it is crucial to examine the effects of R2's level of (un)reliability on the responders' and the Proposer's behavior. The following pivotal finding of our analysis results directly from the observations 3 and 5.²⁸

Result 3. The level of R2's unreliability p (weakly) increases R1's price under both voting rules.

The reasoning underlying this result differs between the two voting rules. Under unanimity rule, the unreliability of one responder makes a Y-vote less attractive for the other responder: Instead of leading to a certain immediate agreement, a Y-vote now signals that R1 values agreement. So a Period 1 Y-vote leads to a lower Period 2 offer than a Period 1 N-vote, thereby reducing the attractiveness of voting Y. Hence, R1's Period 1 price increases because of this *negative signaling value from voting Y*. Under majority rule, the unreliability of R2 makes reaching an agreement in sub-period 1b less likely, thereby reducing R1's *fear of immediate exclusion*. This decreases R1's "costs" of a N-vote in Period 1a and thus leads to a larger Period 1 price of R1.

²⁸In the cases that are not included in these two observations R2's unreliability p does not affect R1's price.

As a consequence, the presence of an unreliable party complicates the process of reaching agreements. This is attributed not only to the reduced probability of a Y-vote from the unreliable party but also to the inflated prices demanded by the other responder. However, the impact on the equilibrium Period 1 offers is less evident because an increased price does not necessarily lead to an increased offer. Under majority rule, P has increased incentives to convince R1 to vote Y. P does not want to solely rely on the unreliable R2 and thus proposes a (weakly) larger offer to R1 (see Proposition 7). At the same time, P's increased willingness to form a coalition with R1, reduces R1's *fear of being excluded* and thus makes him more expensive. So, even though P increases the offer when p becomes larger, R1 is less likely to vote Y in Period 1, leading to more inefficient breakdowns. Conversely, under unanimity rule, the impact of R2's unreliability on the Period 1 offer is ambiguous (see Proposition 8), whereas the probability of breakdown unambiguously increases. All of these insights are outlined by the subsequent result.

Result 4. Under majority rule, the unreliability of R2 (weakly) increases the Period 1 equilibrium offer to R1 and decreases the overall probability of finding an agreement.

Under unanimity rule, the unreliability of R2 has an ambiguous effect on the Period 1 equilibrium offer to R1 and decreases the overall probability of finding an agreement.

Thus, the unreliability of R2 does not inherently result in a lower proposal to R1. However, it does decrease the likelihood of both parties voting Y for a given offer. Consequently, if finding an agreement is efficient, the unreliability of one responder has “additional” negative implications on the overall welfare because it increases the probability of inefficient breakdowns. These negative implications come in “addition” to the “mechanical” effect of one of the parties being unreliable (and therefore by definition being less likely to vote Y) and are based on the “endogenously” decreased willingness of voting Y of the reliable party.

3.7 Extensions and further insights

In this section, I explore additional insights that do not directly follow from the presented model but require slight adjustments or extensions to the model. Details and examples are provided in 3.C.

3.7.1 Larger coalitions

In the model discussed above, MWCs are the only equilibrium outcome under majority rule, even when one of the responders is unreliable. This is specific to the three-player case. If the rational responder R1 announces a Y-vote, it leads to an immediate agreement, giving P no incentive to make a positive offer to the other responder. Although a general analysis is beyond the scope, I consider a five-player model in 3.C.

First, consider a simplified version of our original model, where R1 - just like R2 - is an unreliable robot type. In Period 1, P will form an oversized coalition (OSC)²⁹ and offer c to both responders if

$$c < \frac{p(1 - \delta(1 - c))}{1 + 2p} \text{ and } \delta < \frac{1 - 2c}{1 - c}.$$

OSCs are thus formed when responders are cheap (small c), unreliable (large p), and the probability of a second chance to propose is low (low δ).

Second, consider a more complex scenario with also a rational responder being part of the model. It can be shown that P might still prefer to form an OSC, with the rational responder being included in the coalition. Suppose there are two additional responders (resulting in five players in total), with two of the four responders (say, R2 and R3) being of the unreliable robot type, just like R2 in the original model. Assume R4 is too expensive to be convinced of a Y-vote and R1 is a “rational” responder, with a valuation of agreement

²⁹An OSC is defined as a coalition where more parties receive a positive offer than the at least required number of parties for an agreement to be achieved. In the three player case, an OSC means that positive offers are made to both responders.

that is continuously distributed on $[-1, 0]$. For simplicity, let δ be zero (i.e., there is only one period).³⁰ In equilibrium, P forms an OSC with R1, R2, and R3 if

$$c < \frac{p}{1 + 3p}.$$

Specifically, P offers $x = \frac{p}{1+p}(1 - 2c)$ to R1 and c to R2 and R3.³¹ If p is very small, then P is better off proposing a MWC. Thus, the unreliability of responders indeed increases the likelihood that P forms an OSC, as noted in the following observation.

Observation 6. In an extended model with five players, the presence of unreliable responders leads to (weakly) more parties being included in the winning coalition under majority rule than with reliable parties only.

Including more responders than the minimum required in the coalition reduces the risk of inefficient breakdowns. This strategy is particularly relevant when δ and c are small, i.e., if it is unattractive for P to wait for another round of bargaining and if the unreliable responders are not too expensive. Consequently, in scenarios where parties are not entirely reliable, the occurrence of MWCs should be significantly lower than what theory predicts for situations with fully reliable responders.

The reason why unreliability leads to OSCs is that it leads to uncertainty about the responders' voting behavior. Such uncertainty can also stem from other sources, such as private or incomplete information. As theoretically demonstrated by Tsai and Yang (2010a), uncertainty alone can drive the formation of oversized coalitions under majority rule. Experimental evidence supporting this finding is provided by Piazzolo and Vanberg (2024b).

³⁰As discussed above, OSCs are good options as long as δ is small, i.e., the assumption $\delta = 0$ is not required. However, I use it to simplify the equilibrium analysis.

³¹Note that R1's price is $z = -\frac{2p}{1+p}v$ and thus increasing in p . Consistent with the original model, the unreliability of the other responder(s) makes R1 more expensive. The optimal proposal being offered to R1 is also increasing in p , i.e., R1 is being compensated for the heightened risk of proposal failure.

3.7.2 Asymmetric beliefs about the future

The assumption of incorrect and asymmetric beliefs about δ aligns with real-world scenarios filled with uncertainty, such as negotiations for new climate policies. In these negotiations, different parties may hold varying (and incorrect) expectations regarding the urgency of implementing new measures, influencing their expected probabilities of still reaching an “early enough” new treaty after an initial proposal failure.

The continuation probability δ is a key driver for voting N under unanimity rule. It increases the *positive signaling value from voting N*, making R1 more expensive. Incorrect and asymmetric beliefs about δ can therefore lead to an overestimation of the *positive signaling value from voting N*, possibly resulting in (too) many rejections of Period 1 proposals. In such cases, if parties highly value reaching an agreement, the potential costs of a breakdown under unanimity rule may outweigh the costs of a possible exclusion under majority voting. Consequently, when responders hold asymmetric beliefs about the continuation probability, a shift from unanimity to majority voting may be mutually beneficial for all players, i.e., a Pareto improvement (refer to Lemma 17 in 3.C).

3.8 Concluding remarks

In the realm of multilateral bargaining under private information, the bargaining parties’ strategic considerations depend on the voting rule that is applied. Under unanimity rule, the act of voting “No” carries a distinct *positive signaling value*, making responders costly and agreements hard to reach. Conversely, under majority rule, the *fear of exclusion* associated with voting “No” makes responders more inclined to vote “Yes”, thereby enhancing the likelihood of agreement. Thus, transitioning from unanimity to majority rule consistently favors the proposer and mitigates the risk of inefficient breakdowns and delays. However, such a shift does in general not qualify as a Pareto improvement (with a potential exception being a scenario involving asymmetric beliefs about the continuation probability,

as discussed above).

Despite the advantages of non-unanimous voting rules, parties suffer from the *fear of being excluded*, particularly through the formation of minimum winning coalitions. While theoretical models frequently predict the prevalence of minimum winning coalitions, empirical evidence tells a different story. Both laboratory experiments³² and real-world observations in institutions like the EU Parliament show fewer instances of exclusions than anticipated. In the EU Council, where non-unanimous voting is employed, a remarkable “consensus rate” exceeding 70% has been achieved (see Hayes-Renshaw et al. (2006)).³³ Even when majority rule is applied, there seems to be a strong preference among EU member states (and laboratory participants) for reaching unanimous agreements. In the extended model discussed earlier, we theoretically demonstrate that the presence of unreliable parties may increase the likelihood of forming an “oversized coalition”. Unreliability thus offers a potential explanation for the discrepancy between standard bargaining models’ predictions and empirical observations. However, while minimum winning coalitions appear less frequently than predicted, the threat of potential exclusion still serves as a catalyst for increasing parties’ willingness to agree and compromise. Thus, while the risk of exclusion remains a drawback, it is counterbalanced by the benefits of majority voting, including the higher likelihood of reaching agreements and strengthening an institution’s capacity to act.

This dynamic gains particular relevance in the presence of unreliable parties. In a world where bargaining parties’ announced voting decisions cannot be fully relied on, reaching an agreement becomes ever more difficult. This difficulty arises not only from the inherent decrease in the likelihood of parties voting “Yes”, but, more importantly, from the main result of this paper: The presence of an unreliable party decreases the other parties’ willingness to vote “Yes”. Under majority rule, this is based on a reduced *fear of being ex-*

³²Piazzolo and Vanberg (2024b) find that minimum winning coalitions are proposed in only about one-third of cases, contrary to theoretical expectations.

³³This statistic refers to the period from 1994 to 2004, with recent years showing a consensus rate of over 80% (see Mintel and Ondarza (2022)).

cluded. Reaching an agreement with an unreliable party is harder to be achieved and thus another party's exclusion becomes less likely. Consequently, larger offers are required and the formation of more stable coalitions that include additional parties beyond the minimum requirement is incentivized. Under unanimity rule, in contrast, the larger responders' prices are due to the more pronounced *negative signaling value from voting "Yes"*. Independent of the applied voting rule, the presence of an unreliable Germany therefore poses an increased difficulty for France to persuade Italy to vote "Yes".

Future research could, on one hand, explore an adjusted model in which Germany's level of unreliability is endogenously determined, dependent on the offer received, and can thus be used "strategically".³⁴ This approach would provide further insights into the (un)attractiveness of being perceived as an unreliable bargaining partner, which is likely to vary between different voting rules (see Abreu and Gul (2000) and Ma (2023)).³⁵ On the other hand, future research could explore related theoretical setups where a share of bargaining partners have non-standard preferences.³⁶ Such theoretical analyses would benefit greatly from being complemented by empirical and experimental studies investigating the effects of unreliability in bargaining situations under private information.

³⁴Such model would include Germany as a rational player instead of a robot type.

³⁵Abreu and Gul (2000) show that being perceived as a tough negotiator is advantageous under unanimity rule. In contrast, Ma (2023) demonstrates that under majority voting, the potential for exclusion makes it costly to be seen as an unattractive bargaining partner.

³⁶Cooper and Kagel (2016) discusses other-regarding preferences, noting that our understanding of such dynamics in bargaining games is still incomplete. For example, Montero (2007) shows that in certain conditions under the inequality-aversion model by Fehr and Schmidt (1999), the fear of exclusion may even intensify in bargaining games under majority rule with inequality-averse players.

Appendix

3.A Proofs of main propositions

In the following, the proofs of the Propositions 6, 7, and 8 are presented. Recall that Proposition 5 has followed from the discussions before and has thus been stated without any further proof. The structures of the proofs are very much alike. They use backward induction and present Lemmas representing the results of the following steps. First, Period 2 behavior is analyzed. Then, the Period 1 cutoff type is calculated. Lastly, P's Period 1 maximization problem is solved, leading to the optimal proposals.

3.A.1 Proof of Proposition 6

Lemma 11. In Period 2, under unanimity rule, P proposes

$$x^2 = \begin{cases} (0, c) & \hat{v} > 1 - c, \\ \left(\frac{1-c-\hat{v}}{2}, c\right) & \hat{v} \in [c-1, 1-c], \\ FAIL & \hat{v} < c-1. \end{cases}$$

Proof. Given $x^2 = (x_1^2, c)$, R1's probability of voting Y is $\frac{\hat{v}+x_1^2}{\hat{v}+1}$ and P's Period 2 utility thus amounts to $EU_P(x^2 = (x, c)) = \frac{\hat{v}+x}{\hat{v}+1}(1-x-c)$. Maximizing this over x leads to $x = \frac{1-c-\hat{v}}{2}$. Here $x + c = \frac{1+c-\hat{v}}{2} \leq 1 \Leftrightarrow c - \hat{v} \leq 1$ (P only has a budget of one) and $x \geq 0 \Leftrightarrow c + \hat{v} \leq 1$ (offers must be positive) are required, i.e., $\hat{v} \in [c-1, 1-c]$. If $\hat{v} < c-1$, then P prefers to offer a proposal that fails for sure $x^2 = FAIL$ (agreement is just too expensive) leading to $EU_P(x^2 = FAIL) = 0$. If $\hat{v} > 1-c$, then P offers $x^2 = (0, c)$ leading to $EU_P(x^2 = (0, c)) = \frac{\hat{v}}{\hat{v}+1}(1-c)$. Given that $\hat{v} \in [c-1, 1-c]$, $EU_P(x^2 = (x, c)) = \frac{(1-c+\hat{v})^2}{4(1+\hat{v})}$. $\square$

In Period 1, P basically has two options. She can either propose an offer that is sure to fail $x^1 = FAIL$ (e.g., by choosing $x_2^1 < c$), which thus leads to $\hat{v} = 1$, or she can offer $x^1 = (x_1^1, c)$.

Lemma 12. Given $x^1 = (x, c)$, R1 votes Y iff $v \geq \hat{v} = \frac{\delta(1-c)-2x}{2-\delta}$.

Proof. R1 is indifferent between voting Y and N if

$$x + v = \delta \begin{cases} \max\{v, 0\} & \hat{v} > 1 - c, \\ \max\{v + \frac{1-c-\hat{v}}{2}, 0\} & \hat{v} \in [c-1, 1-c], \\ 0 & \hat{v} < c-1 \end{cases}$$

(LHS is R1's utility from voting Y and RHS from voting N) and $v = \hat{v}$. Hence R1's cutoff

$$\text{type is } \hat{v} = \begin{cases} \frac{\delta(1-c)-2x}{2-\delta} & \hat{v} \in [c-1, 1-c], \\ -\frac{x}{1-\delta} & \hat{v} > 1-c, \\ -x & \hat{v} < c-1. \end{cases} \quad \text{Note that we can not be in the upper case}$$

because $\hat{v} \leq 0$ contradicts $\hat{v} > 1-c$. Also note that $x \in [0, 1-c]$ and we thus can also not be in the lower case. Hence, as $x \in [0, 1-c]$, $\hat{v} = \frac{\delta(1-c)-2x}{2-\delta} \in [c-1, \frac{\delta}{2-\delta}(1-c)]$. $\square$

Lemma 13. P's optimal Period 1 offer is $x^1 = \left(\max \left\{ 0, \frac{\delta(1-\delta)-(2-\delta-\frac{\delta^2}{2})c}{4-3\delta} \right\}, c \right)$.

Proof. Recall from above that P's expected Period 2 utility after a N-vote of R1 is $EU_P^2 = \frac{(1-c+\hat{v})^2}{4(1+\hat{v})}$. Also, P knows that $\hat{v} = \frac{\delta(1-c)-2x}{2-\delta}$ and will in Period 1 thus choose x such that $EU_P((x, c), ((\frac{(1-\delta)(1-c)+x}{2-\delta}, c))) = \frac{1-\hat{v}}{2}(1-x-c) + \delta \frac{\hat{v}+1}{2} \frac{(1-c+\hat{v})^2}{4(1+\hat{v})}$ is maximized. This leads to $x = \frac{\delta(1-\delta)-(2-\delta-\frac{\delta^2}{2})c}{4-3\delta}$ which is positive if R2 is cheap and δ of some intermediate value. Otherwise, P must choose $x^1 = (0, c)$ and thus $\hat{v} = \frac{\delta}{2-\delta}(1-c)$, $x_1^2 = \frac{1-\delta}{2-\delta}(1-c)$, and $EU_P((0, c), (\frac{1-\delta}{2-\delta}(1-c), c)) = \frac{2(1-\delta)+\delta c}{2(2-\delta)}(1-c) + \frac{\delta}{2}(\frac{1-c}{2-\delta})^2$. P's second option would be to propose $x^1 = FAIL$ and $x^2 = (0, c)$. This would lead to $EU_P(FAIL, (0, c)) = \frac{\delta}{2}(1-c)$ which can be shown to be smaller than $EU_P((0, c), (\frac{1-\delta}{2-\delta}(1-c), c))$ and thus smaller than $EU_P((\frac{\delta(1-\delta)-(2-\delta-\frac{\delta^2}{2})c}{4-3\delta}, c), (x_1^2, c))$. $\square$

This completes the proof of Proposition 6. $\square$

3.A.2 Proof of Proposition 7

In sub-period 2a, R1 will be offered $x = 0$ and he votes Y. That is because after a N-vote, P approaches R2 and secures an agreement with certainty (by offering c). In sub-period 1b, after R1 has voted N, P will offer c to R2 if $(1 - p)(1 - c) + p\delta \geq \delta$, i.e., if $c \leq 1 - \delta$.

Suppose $c \leq 1 - \delta$. Then, in sub-period 1a, R1 votes Y on an offer x if $x + v \geq (1 - p)v + p\delta v$, i.e., if $x \geq -(1 - \delta)pv = z$ or $v \geq \hat{v} = -\frac{x}{(1 - \delta)p}$. So R1 votes Y with probability $\frac{1 + \frac{x}{(1 - \delta)p}}{2}$, given that $\frac{x}{(1 - \delta)p} < 1$ (otherwise R1 votes Y for sure). P, in this case, chooses x such that $\frac{1 + \frac{x}{(1 - \delta)p}}{2}(1 - x) + \frac{1 - \frac{x}{(1 - \delta)p}}{2}((1 - p)(1 - c) + p\delta)$ is maximized, leading to $x = \begin{cases} \frac{(1 - p)c}{2} & p > \frac{c}{2 - 2\delta + c}, \\ (1 - \delta)p & \text{otherwise} \end{cases} = \min\{\frac{(1 - p)c}{2}, (1 - \delta)p\}.$

Suppose $c > 1 - \delta$. Then, in sub-period 1a, R1 votes Y on an offer x if $x + v \geq \delta v$, i.e., if $x \geq -(1 - \delta)v = z$ or $v \geq \hat{v} = -\frac{x}{(1 - \delta)}$. R1 votes Y with probability $\frac{1 + \frac{x}{(1 - \delta)}}{2}$ and P thus maximizes $\frac{1 + \frac{x}{(1 - \delta)}}{2}(1 - x) + \frac{1 - \frac{x}{(1 - \delta)}}{2}\delta$, leading to $x = 0$.

This completes the proof of Proposition 7. $\square$

3.A.3 Proof of Proposition 8

First, recall that the sequence in which responders are approached does not matter. In Period 2, responders' announcements are truthful, exactly as in the "reliable" case. Therefore, Lemma 11 still holds when R1 has voted N in Period 1. Additionally, we must consider the scenario where R1 has voted Y, yet a Period 1 agreement has not been reached.

Lemma 14. After R1 has voted Y in Period 1, P, under unanimity rule, proposes $x^2 = (0, c)$.

Proof. After a R1-Y-vote in Period 1, P believes R1's valuation of agreement to be distributed on $v \in [\hat{v}, 1]$. So, given $x^2 = (x, c)$, R1's probability of voting Y is $\frac{1 + x}{1 - \hat{v}}$ if $x < -\hat{v}$

and 1 otherwise (he votes Y whenever $v > -x$). Given that $x < -\hat{v}$, P's Period 2 utility amounts to $EU_P(x^2 = (x, c)) = \frac{1+x}{1-\delta}(1-x-c)$. Maximizing this over x leads to $x = -c/2$. Hence, the optimal (and feasible) offer is $x^2 = (0, c)$ in all cases. $\square$

Lemma 15. Given $x^1 = (x, c)$, R1 votes Y iff $v \geq \hat{v} = \begin{cases} \frac{\delta(1-c)-2(1-p)x}{2(1-p)(1-\delta)+\delta} & \hat{v} \in [0, 1-c], \\ \frac{\delta(1-c)-2(1-p)x}{2(1-p)-\delta} & \hat{v} \in [c-1, 0]. \end{cases}$

R1's Period 1 price thus amounts to $z(v) = \begin{cases} -(1-\delta)v + \frac{\delta(1-c-v)}{2(1-p)} & \hat{v} \in [0, 1-c], \\ -v + \frac{\delta(1-c+v)}{2(1-p)} & \hat{v} \in [c-1, 0], \end{cases}$ which is increasing in p .

Proof. Voting Y gives R1 an expected utility of $(1-p)(x+v)+p\delta \max\{v, 0\}$. Voting N leads

to an expected utility of $\delta \begin{cases} \max\{v, 0\} & \hat{v} > 1-c, \\ \max\{v + \frac{1-c-\hat{v}}{2}, 0\} & \hat{v} \in [c-1, 1-c], \\ 0 & \hat{v} < c-1. \end{cases}$ So R1 is indifferent be-

tween Y and N if $v = \hat{v}$ and $(1-p)(x+v)+p\delta \max\{v, 0\} = \delta \begin{cases} \max\{v, 0\} & \hat{v} > 1-c, \\ \max\{v + \frac{1-c-\hat{v}}{2}, 0\} & \hat{v} \in [c-1, 1-c], \\ 0 & \hat{v} < c-1. \end{cases}$

From this we obtain the cutoff type $\hat{v} = \begin{cases} -\frac{x}{1-\delta} & \hat{v} > 1-c, \\ \frac{\delta(1-c)-2(1-p)x}{2(1-p)-(1-2p)\delta} & \hat{v} \in [0, 1-c], \\ \frac{\delta(1-c)-2(1-p)x}{2(1-p)-\delta} & \hat{v} \in [c-1, 0], \\ -x & \hat{v} < c-1. \end{cases}$ Note that we can

neither be in the upper case (because $\hat{v} \leq 0$ contradicts $\hat{v} > 1-c$) nor in the lowest one (be-

cause $x \in [0, 1-c]$). Consequently, the cutoff type is $\hat{v} = \begin{cases} \frac{\delta(1-c)-2(1-p)x}{2(1-p)(1-\delta)+\delta} & \hat{v} \in [0, 1-c], \\ \frac{\delta(1-c)-2(1-p)x}{2(1-p)-\delta} & \hat{v} \in [c-1, 0]. \end{cases}$

So R1's price is $z(v) = \begin{cases} -(1-\delta)v + \frac{\delta(1-c-v)}{2(1-p)} & \hat{v} \in [0, 1-c], \\ -v + \frac{\delta(1-c+v)}{2(1-p)} & \hat{v} \in [c-1, 0]. \end{cases}$ Hence, the price of R1 is

increasing in p . □

Lemma 16. P's optimal Period 1 offer is

$$x^1 = \left(\max \left\{ \frac{(1-\delta)\delta - (1-\delta)c(2+\delta-2p+2p\delta) - \frac{\delta^2}{2(1-p)}c}{4(1-p)(1-\delta) + \delta}, 0 \right\}, c \right).$$

Proof. P chooses x such that the following expression is maximized:

$$\begin{aligned} \frac{1-\hat{v}}{2} \left((1-p)(1-x-c) + p\delta \max \left\{ \frac{1}{1-\hat{v}}, 1 \right\} (1-c) \right) \\ + \frac{\hat{v}+1}{2} \delta \frac{\hat{v} - \frac{1-c-\hat{v}}{2}}{\hat{v}+1} \left(1-c - \frac{1-c-\hat{v}}{2} \right). \end{aligned}$$

Given that $\hat{v} > 0$, this leads to the following Period 1 offer:

$$x = \frac{(1-\delta)\delta - (1-\delta)c(2+\delta-2p+2p\delta) - \frac{\delta^2}{2(1-p)}c}{4(1-p)(1-\delta) + \delta} \text{ or } x = 0.$$

Given $\hat{v} < 0$, the only equilibrium solution is:

$$x = \frac{\delta(1-c)}{2(1-p)},$$

which is dominated by:

$$x = \max \left\{ \frac{(1-\delta)\delta - (1-\delta)c(2+\delta-2p+2p\delta) - \frac{\delta^2}{2(1-p)}c}{4(1-p)(1-\delta) + \delta}, 0 \right\},$$

leading to $\hat{v} > 0$. □

3.B Additional results

In this section, we have a look at some additional insights directly resulting from our model.

3.B.1 The responder's price

Note that under unanimity rule, R1's behavior for intermediate values of v is of our main interest. If R1 likes agreement very much, he will vote Y anyway: risking a breakdown is not worth it. If R1 dislikes agreement very much, he will vote N anyway: The pie is not large enough to compensate him sufficiently and he can be sure that there will be no agreement without his consent. Let us thus concentrate on $v \in (-1, 1 - c)$ in the following. The following result is equivalent to Result 1.

Result. R1 is (weakly) more willing to vote Y under majority rule than under unanimity rule because:

- If R1 negatively values reaching an agreement ($v < 0$): R1's Period 1 price under majority rule $z(v)^m = \begin{cases} -(1 - \delta)pv & c \leq 1 - \delta, \\ -(1 - \delta)v & c > 1 - \delta \end{cases}$ is lower than his price under unanimity rule $z(v)^u = \frac{\delta(1-c) - (2(1-p)(1-\delta) + \delta)v}{2(1-p)}$.
- If R1 positively values reaching an agreement ($v \geq 0$): R1, in Period 1, votes Y on any offer under majority rule.

Proof. Given that $v < 0$, R1's price under unanimity rule is larger than his price under majority rule: If $c > 1 - \delta$, then $\frac{\delta(1-c) - (2(1-p)(1-\delta) + \delta)v}{2(1-p)} > -(1 - \delta)v \Leftrightarrow \delta(1 - c - v) > 0$. If $c \leq 1 - \delta$, then $\frac{\delta(1-c) - (2(1-p)(1-\delta) + \delta)v}{2(1-p)} > -(1 - \delta)pv \Leftrightarrow \delta(1 - c - v) > 2(1 - p)^2(1 - \delta)v$. Both cases are true because $1 - c - v > 0$ as $v < 0$. $\square$

3.B.2 The probability of an overall breakdown

is the same as the probability of not finding an agreement and depends crucially on the voting rule that is applied. The following result is equivalent to Result 2.

Result. Under majority rule, the probability of a breakdown is lower than under unanimity rule.

Proof. Under majority rule: If $c > 1 - \delta$, R2 is offered zero in Period 1 and R1 votes N with probability $\frac{1}{2}$ (if $v \geq 0$). Hence, breakdown occurs with probability $\frac{1-\delta}{2}$. If $c \leq 1 - \delta$, R2 is offered c in Period 1 and votes N with probability p . R1, in sub-period 1a, is offered $\tilde{x}$ and votes Y if $v \geq -\frac{\tilde{x}}{(1-\delta)p}$. So the probability of breakdown is even smaller than in the case where $c > 1 - \delta$, i.e., it is $\in [0, \frac{1-\delta}{4}]$. More precisely, it is zero if $p < \frac{\tilde{x}}{1-\delta}$ and would be $\frac{1-\delta}{4}$ if $\tilde{x} = 0$ and $p = \frac{1}{2}$.

Under unanimity rule: there is breakdown with probability $\frac{2-\delta c}{2(2-\delta)}((1-\delta) + \delta \frac{1-\delta c+c}{2-\delta c}) = \frac{1}{2}$ if R2 is reliable ($p = 0$). If $p > 0$, then - as shown before - not only R2 is less likely to vote Y but also R1's willingness to vote Y shrinks. Consequently, the probability of breakdown must be weakly larger than in the "reliable" case. Consequently, the probability of breakdown is $\geq \frac{1}{2}$ under unanimity rule and $< \frac{1}{2}$ under majority rule. $\square$

3.B.3 Welfare implications

Result. The application of unanimity rule leads to more inefficient breakdowns and less inefficient agreements than the application of majority rule.

Proof. Suppose $v < c - 1$. Then having a breakdown is welfare optimizing. Whereas under unanimity rule there sure is a breakdown, it is still quite likely that there is an agreement under majority rule. Hence unanimity rule should be preferred over majority rule from a welfare perspective.

Suppose $v > c - 1$. Then it follows directly from Result 2 that an inefficient breakdown is more likely under unanimity rule than under majority rule. $\square$

Note that under unanimity rule, R1 might vote N on positive Period 1 offers even if he positively values agreement. That is, a breakdown might even occur in cases where ending up with a breakdown is very inefficient.

Example 1. Take $c = \varepsilon$, $\delta = 1/2$, $v = 1/3 - \varepsilon$, and $p = 0$, with ε close enough to zero. In this scenario, an agreement results in a net benefit of $4/3 - 2\varepsilon$ compared to a

breakdown. Still, under unanimity rule, a breakdown occurs half of the times (as R1 votes N on $x^1 = (0, \varepsilon)$). The (possible) Period 2 offer is $x^2 = (\frac{1-\varepsilon}{3}, \varepsilon)$. So expected profits are $\frac{1}{3} - \frac{2}{3}\varepsilon$ for R1 and $\varepsilon/2$ for R2.

In contrast, the application of majority rule leads to a certain Period 1 agreement ($x^1 = (0, \varepsilon)$) and thus to expected profits of $\frac{1}{3} - \varepsilon$ for R1 and ε for R2. Notably, P is strictly better off in the latter case.

Thus, even in the most extreme scenario where the application of unanimity rule results in many inefficient and costly breakdowns, opting for majority rule does not lead to a Pareto improvement. This might change if there is asymmetry in the expected continuation probability δ .

3.C Extensions

Now, let us turn to some extensions of the presented model.

3.C.1 Larger coalitions in a finite player game

Extension 1 Suppose both responders are of the unreliable cutoff type, with $c < \frac{1}{2}$ and $p < \frac{1}{2}$. Then, P will decide between three options: First, not offering anything in Period 1 and just “waiting” for Period 2 to be reached, leading to $EU = \delta(1 - c)$. Second, approaching one of the responders and offering him c , leading to $EU = (1-p)(1-c) + p\delta(1-c)$. Third, offering c to both responders, resulting in $EU = (1-p^2)(1-2c) + p^2\delta(1-c)$.

P prefers the latter option over the first one if $\delta < \frac{1-2c}{1-c}$ and the latter over the second one if $c < \frac{p(1-p)(1-\delta(1-c))}{1+p-2p^2} = \frac{p(1-\delta(1-c))}{1+2p}$. Hence, P tries to form an oversized coalition (OSC) if

$$c < \frac{p(1-\delta(1-c))}{1+2p} \text{ and } \delta < \frac{1-2c}{1-c}.$$

Extension 2 Suppose that there are two additional responders (i.e., five players in total) and a simple majority rule is applied. Thus, there is an agreement if at least two of the

four responders vote Y.³⁷ Suppose that two of the four responders (R2 and R3) are of the unreliable robot type, just like R2 in the original model: They both announce a Y-vote whenever offered at least c but then still end up voting N with probability $p < \frac{1}{2}$. R4 is of a reliable robot type but too expensive to be convinced of a Y-vote (e.g., he votes Y only if offered more than one). R1 is the responder of interest, like in the original model. However, R1's valuation of agreement now is continuously distributed on $[-1, 0]$.

In Period 2, all responders are reliable. P will approach R1 first, make him a zero offer, and R1 votes Y. That is because R1 knows that a N-vote would lead to a certain agreement with R2 and R3, while himself being excluded.

In Period 1, R1 will again be approached first:

- Suppose R1 has voted N. Then, P will have to decide whether she wants to offer c to R2 and R3 or just wait for the next period to be reached. The former is more beneficial than the latter if $(1-p)^2(1-2c) + (1-(1-p)^2)\delta(1-c) > \delta(1-c)$, i.e., if $c < \frac{1-\delta}{2-\delta}$ (for $\delta = 0$, this holds true because $c < 1/2$ is assumed).
- Suppose R1 has voted Y on the offer x . Then, P must decide whether she wants to offer c to both R2 and R3 or just to R2.³⁸ The former is more beneficial than the latter if $(1-p^2)(1-x-2c) + p^2\delta(1-c) \geq (1-p)(1-x-c) + p\delta(1-c)$, i.e., if $x \leq (1-\delta)(1-c) - \frac{1+p}{p}c$ (for $\delta = 0$, the condition is $x \leq 1 - \frac{1+2p}{p}c$).

Thus, building an OSC can only be optimal if responders are sufficiently unreliable (p not too small), responders not too costly (c small), and the continuation probability not too large (δ small): With reliable responders a MWC is optimal. If responders are expensive, an OSC becomes too expensive for P. If the next round is reached with high probability, then P is better off by risking no agreement today and building a MWC tomorrow.

For simplicity, suppose in the following that Period 2 will never be reached, i.e., $\delta = 0$.

³⁷Recall that P is “assumed” to always vote Y.

³⁸Waiting for the next round to be reached is on equilibrium path not optimal as she would then not have offered x to R1 in the first place.

We will now look at the cases where the Period 1 offer x is small, such that P proposes an OSC after a Y-vote of R1, i.e., where $x \leq 1 - \frac{1+2p}{p}c$. Note that an offer larger than this is not even feasible for P if c is sufficiently small. Thus, it remains to be shown that P indeed wants to make a positive offer to R1 in such cases where $\delta = 0$ and c is not too large.³⁹

Suppose R1 faces an offer $x \leq 1 - \frac{1+2p}{p}c$ in Period 1a. Then, he votes Y whenever $(1-p^2)(x+v) + p^2 \geq (1-p)^2v + (1-(1-p)^2)$, i.e., if

$$v \geq -\frac{(1+p)x}{2p} \equiv \hat{v}.$$

R1 thus votes Y with probability $-\hat{v}$ and P therefore chooses her optimal offer x in order to maximize $-\hat{v}(1-p^2)(1-x-2c) + (1+\hat{v})(1-p)^2(1-2c)$. This leads to an optimal offer of

$$x = \frac{p}{1+p}(1-2c),$$

which is indeed smaller than $1 - \frac{1+2p}{p}c$ if $c < \frac{p}{1+3p}$ (otherwise we would have a corner solution with $x = \max\{0, 1 - \frac{1+2p}{p}c\}$).

Note that R1's price is

$$z = -\frac{2p}{1+p}v$$

and thus increasing in p . In line with the original model, the unreliability of the other responders makes R1 more expensive. The optimal proposal to R1 is also increasing in p , i.e., R1 is being compensated for the increased risk of proposal failure.

Note that if p is very small, then offering $x \leq 1 - \frac{1+2p}{p}c$ does not work and P would be better off by proposing a MWC. Thus, the unreliability of the other responders makes it indeed likely that P forms an OSC. Particularly, this is the case if δ and c are small, i.e., if it is unattractive for P to wait for another round of bargaining and if the unreliable

³⁹If offering $x > 1 - \frac{1+2p}{p}c$ would be feasible and would be offered, R1 votes Y whenever $(1-p)(x+v) \geq (1-p)^2v$, i.e., if $v \geq -\frac{x}{p} \equiv \hat{v}$. P thus maximizes $-\hat{v}(1-p)(1-x-c) + (1+\hat{v})(1-p)^2(1-2c)$, leading to $x = \frac{c+(1-2c)p}{2}$. This is only larger than $1 - \frac{1+2p}{p}c$ if c is large. Hence, as discussed above, when focusing on small c , the case $x > 1 - \frac{1+2p}{p}c$ becomes irrelevant for on-equilibrium path behavior.

responders are not too expensive.

3.C.2 The continuation probability delta

The continuation probability δ is one of the main drivers for voting N under unanimity rule. It increases the *positive signaling value from voting N* and thus makes R1 more expensive. Consequently, incorrect beliefs about δ can lead to (too) many rejections of Period 1 proposals. For simplicity, assume $p = 0$ in the following.

Lemma 17. Given that R1 overestimates the probability to go into a second round of bargaining (i.e., $\hat{\delta}_R > \delta^{40}$), applying majority rule instead of unanimity rule might be a Pareto improvement.

Proof. Take $c = \varepsilon$, $\hat{\delta}_R = 3/4 > \delta = 1/2$ and $v = 3/5 - \varepsilon$, with ε close enough to zero. Under unanimity rule, P proposes $x^1 = (0, \varepsilon)$, R1 votes N (as $v < \hat{v} = \frac{\hat{\delta}_R}{2 - \hat{\delta}_R}(1 - \varepsilon)$), and if Period 2 is reached (with probability $\frac{1}{2}$), P proposes $x^2 = (\frac{1 - \hat{\delta}_R}{2 - \hat{\delta}_R}(1 - \varepsilon), \varepsilon)$. So expected profits are $\frac{1}{2}(\frac{1}{5}(1 - \varepsilon) + \frac{3}{5} - \varepsilon) = \frac{2}{5} - \frac{3}{5}\varepsilon$ for R1 and $\varepsilon/2$ for R2 under unanimity rule.

Under majority rule, there is an immediate agreement on $x^1 = (0, \varepsilon)$ and profits are $\frac{3}{5} - \varepsilon$ for R1 and ε for R2. So here switching from unanimity rule to majority rule is Pareto efficient (P is always better off under majority rule). $\square$

⁴⁰ $\hat{\delta}_R$ is defined as the (incorrect) belief of R1 about the continuation probability δ .

Chapter 4

Don't put all your legs in one basket:

Theory and evidence on coopetition in road cycling¹

Abstract

We study competition between two groups of individuals with team affiliations, where each group solves a coopetition problem to outperform the other group. Our analysis suggests the presence of a strategic benefit of diversification that goes beyond merely reducing outcome uncertainty. We outline application in industrial and workplace organization and provide a detailed model of road cycling races, which naturally feature this strategic setup. We find that asymmetric groups tend to cooperate better. Also, having team members in two competing groups is beneficial for a team, as it increases free-riding opportunities in both groups. By analyzing data from over 40 seasons of professional road cycling races, we find empirical evidence in favor of these results. In particular, having a teammate in a group behind positively impacts win probability.

JEL codes: D74; Z20; C79

Keywords: coopetition; free-riding; diversification; coordination; sports economics

¹This paper is jointly written with Julian Matthes and has been accepted for publication in the *European Economic Review*.

4.1 Introduction

The term *coopetition* describes cooperation among competitors. It was pioneered in the management literature by Brandenburger and Nalebuff (2011); for reviews see Bouncken et al. (2015) or Gernsheimer et al. (2021). In this paper, we identify a previously unstudied variant of the coopetition problem which is frequently observable in professional road cycling. We provide a thorough theoretical and empirical analysis of this particular situation and explain how our results translate beyond cycling.

Road cycling races naturally display coopetition: Because of the possibility of free-riding by riding behind another rider, the first group of riders (the breakaway) has to repeatedly solve a volunteer’s dilemma. Someone needs to ride in front in order not to get caught. The act of riding in front is, however, costly, because investing energy early in the race decreases the chances to win the race in the final sprint against the other riders in the front group. This strategic situation is similarly present in chasing groups of riders. In other words, competing groups of riders engage in intra-group coopetition throughout the race. The fact that riders compete in teams, not individually, adds to the strategic complexity of the situation. As we will see in this paper, it is not immediately obvious how a team would want to distribute their riders across groups in different situations, if given the chance.²

To our knowledge, this paper is the first to study this situation of multiple coopetition problems persisting side by side, with players self-selecting into these problems “strategically”. Abstractly, we consider scenarios with at least two “groups” of agents, where the groups compete against each other, and their success depends on how well agents cooperate within their group. Simultaneously, participating in the between-group competition weakens agents for the following intra-group competition and thereby decreases their share of

²The idea of distributing riders across groups is more realistic than it may seem: Road cycling races are several hours long and normally begin by a prolonged phase of “breakaway formation”, in which teams attempt to place riders in the front group. This front group very rarely wins, hence serves a primarily strategic function.

the group's overall payoff. Thus, the problem of interest involves both intra-group cooperation and inter-group competition. If players can distribute agents across groups, there is a trade-off between being strongly presented in one group or less strongly presented in several. We will show theoretically and empirically that being presented in several groups is often beneficial, because it provides the agent with free-riding opportunities in both groups.

While the example we use to present our general insights is road cycling, we believe that the discussed problem is interesting in itself as there are many situations outside of cycling where similar strategic structures occur. For instance, take the tourism sector. The central role of coopetition in the tourism industry is discussed by Chim-Miki and Batista-Canino (2017) and empirically confirmed by Della Corte and Aria (2016). The latter use data from tourist destinations in Italy and find that coopetition affects performance positively. Wang and Krakover (2008) focus on tourism industry stakeholders in the United States and conclude that stakeholders' perceived relationship between cooperation and competition impacts the marketing campaigns of a destination. Another example is intra-port coopetition. Kavirathna et al. (2019) discuss the dynamics under different combinations of terminal ownership: A terminal owner profits from other terminal owners' investments in projects that make the overall port more attractive, while simultaneously competing with them for a larger market share. Our paper presents more general results on competing investors who consider to contribute funding to some public good. It also goes beyond the examples mentioned above in that it analyzes how the dynamics between investors change if some of them have also investments in competing projects (e.g., in competing tourism destinations or in competing (air)ports).

To see this, consider for instance two neighbouring islands (A and B), on which three investors (X, Y, and Z) compete for tourists to visit their hotels. Investor X has hotels on both islands, while investor Y only has a hotel on island A, and investor Z only a hotel on island B. Each of the islands is also competing against other tourist destinations across

the world, giving the investors on each island a good reason to cooperate and collaborate at a local level to compete effectively on an international level (as in Edgell and Haenisch (1995)). Let's say islands A and B both need to modernize in order to stay competitive as tourist destinations. An infrastructure intervention, like a docking station for speed-boats bringing tourists to the island, would do the trick. This docking station would benefit each investor on the island, creating free-riding incentives: Each investor wants the other investors to build the docking station. If there was only one island, this is a classical coopetition scenario and investors might join forces and build it together. In the situation with two islands and one diversified investor, however, the investors differ in bargaining power due to the presence of the twin problem on the other island. Investor X can refer to her hotels on island A to convince investor Z to build the docking station on island B, and to her hotels on island B to convince investor Y to build the docking station on island A. Thus, investor X reaps strategic benefits of diversification. The island example can easily be seen to be similar to the process of urban gentrification: Franchises profit from marketing and infrastructure interventions that are delegated, by the mechanism explained above, to small entrepreneurs that rely on their neighborhood being popular. Consequently, the discussed mechanisms contribute to the market power of large brands and might have to be considered when evaluating mergers or acquisitions.

For another example in a completely different setting, take two PhD students that are about to enter the job market while jointly working on a research project and applying for the same faculty position. Imagine that student A has diversified and is part of a second project with some other co-workers, while student B solely relies on the joint project to demonstrate his skills. This puts student B in an uncomfortable situation: Student A can always refer to her other project to make him work harder on their joint project.

Each of the examples mentioned above would need careful individual modelling to understand the optimal behavior of the parties involved. We refrain from focusing on these scenarios in this paper and instead turn to analyze road cycling, which naturally

features the incentive structure of interest, in order to gain some general insights on the questions posed in the previous paragraphs. This decision was made for several reasons: Firstly, interactions in road cycling races are easier to capture in the framework of a game, because races have well-defined rules and incentives are quite clear. Secondly, we can empirically verify our theoretical results by analyzing historical results of professional road cycling races, of which there are many (publicly) available. We were able to compile a large dataset of situations that resemble the problem we are interested in with slight variations. We only collected data on races of the highest level, where stakes for each rider and team are substantial. This makes deviations from rational behavior in these races very costly.

Let us now turn to the precise problem we study from here on, which is coopetition in road cycling. Road cycling is famously strategically rich, it is sometimes even referred to as *chess on wheels*. This is not due to a complicated set of rules, but instead a consequence of a) the possibility of free-riding, and b) the fact that while individual riders win races, those riders are organized in teams. Free-riding incentives exist because riding behind other riders, a practice referred to as *drafting* or *slipstreaming*, significantly reduces the required energy to hold a given speed (up to 40 per cent, see for example Dilger and Geyer (2009)). Consequently, cycling races naturally feature the formation of groups³ on the road. Individual riders find it challenging to break away from a group, and a well-coordinated large group can either distance itself from or catch up with a smaller group, provided proper coordination (with members taking turns at the front) is maintained. The riders therefore face an intra-group *coopetition*-problem: Riders have an interest to cooperate within their group early in the race, but will eventually compete against their group members at some later point. Simultaneously, there is an inter-group competition problem: Only riders of a group that reaches the finish line first bear a chance to sprint for the win. In addition, there is a team-based organization of individual riders. Each racing team comprises several

³We define teams as a set of riders that belong to the same team and groups as a set of riders that rides within a short distance at a respective point in time. Groups might thus consist of riders from various teams.

riders with varying individual capabilities. Riders are connected to their team manager in a car following the race via radio at all times, making each team act as a strategic unit.⁴ This sets apart coopetition dynamics in cycling from the general coopetition literature and introduces the option to simultaneously “invest” into competing groups.

An exhaustive equilibrium analysis of a multi-hour bike race certainly exceeds the scope of a game-theoretic examination. Instead, we address one specific question teams face in the final part of a race: What value (in terms of win-probability) does a team gain by adding another rider to either the leading or chasing group? To shed light on this, we explore a related question: What group dynamics indicate effective coordination, enabling groups to either maintain distance from or close the gap with other groups? We model the situations of interest as one-shot positioning games with win probabilities as payoffs, featuring players (the teams) with multi-dimensional action spaces (one action per rider), representing pacing strategies of the riders. We assume each rider has an exogenously assigned level of energy at their disposal for the entirety of the race and is fully controlled by their team. The setup of the race is captured by tracking the positions and energy levels of each individual rider. A rider’s actions in the game cost a certain amount of energy and a team’s win probability in the sprint is proportional to the remaining energy of their strongest rider in the first group of the race.⁵

Although our modeled one-period simultaneous-move games may appear limiting, road cycling races often hinge on split-second decisions⁶ at pivotal race segments familiar to all riders.⁷ These critical junctures may occur just before the final sprint or earlier, such as at the conclusion of the race’s final climb, after which the formed groups proceed to the sprint.

⁴This adds an interesting component to the coopetition dynamics: Heterogeneity among competitors exists along two dimensions, as competitive advantages can be attained by being stronger or by having a greater number of (stronger) teammates available to control the race situation.

⁵We will discuss why we choose to have one designated sprinter per team in Section 4.2.

⁶The benefit of following a decisive attack only exists when the decision to follow is made simultaneously with the other rider’s decision to attack.

⁷The most famous example is the almost 300km long one-day race Milan-San Remo, which is notoriously boring until riders try to break away at the steep section of the Poggio, the six-minute long final climb of the race starting only 10km from the finish.

Notably, cycling teams strategically compose their line-ups based on race course profiles⁸ and brief their riders before a race on optimal behavior in possible scenarios that may arise at these critical moments (see Croxton (2023)), justifying our approach of focusing on one period only.

We document the following theoretical findings: In order for a group to *coordinate* well, there needs to be consensus about who is required to exert the most effort by riding at the front. One thing that leads to such consensus in the final phase of the race is what we will call *asymmetry* in a group. Individual capacity disparities, particularly when one rider stands out as the strongest, naturally designate him to lead the group. Similarly, team strength imbalances can dictate group dynamics. If one team has several riders in a group, they can afford to sacrifice riders with minimal costs, given that only their strongest rider is expected to compete in the sprint, prompting the group to demand that team to take the lead. From a team's standpoint, this finding underscores the strategic advantage of having riders spread across competing groups over concentrating them in a single group, surpassing mere diversification. If indeed a team has riders in several groups, each of these riders benefits from their teammate serving as an outside option, reducing the respective stakes in the success in the inter-group competition and thus enhancing free-riding opportunities in that group. This effect stands out even more because placing several riders in one group may prove detrimental to a team. For instance, take a situation where Team A dominates a group with multiple riders, while other teams have individually stronger but single riders. Then, there will be consensus on Team A bearing the burden of leading the group. Although this may lead to successful coordination within the group, all group members, not just Team A's, reap the benefits. Conversely, if Team A had only one rider, the burden would shift to the strongest rider of the group, aligning with Team A's strategic interests of saving comparably more energy than the in-group opponents.

Our theoretical analysis is complemented by empirical findings supporting our propo-

⁸Refer to Appendix A for a case study of how Team Alpecin-Deceuninck used Mathieu van der Poel and Jasper Philipsen in order to maximize free-riding in the 2024 classics season.

sitions. We use results data from real, high-stakes professional cycling races, which we collected from ProCyclingStats.com, one of the largest online databases for cycling data. The dataset consists of stage results from over 40 seasons of the three Grand Tours (three-week stage races) and eight one-week stage races.⁹ Also, we use the final results from eight one-day races as a robustness check. We identify races that were decided between small groups of riders and run fixed-effects regressions to discern the characteristics associated with finishing in the front group and winning the race, respectively. Examining the properties of groups that finish together reveals intriguing insights. Despite the considerable benefits of riding in a group, it is remarkable that many cycling races are won by a single rider with a significant gap over a chasing group. By comparing groups that finish together in a sprint with those trailing behind a solo winner or scattered groups in close proximity at the finish, we gain insights into the group dynamics that foster coordination. Consistent with our hypotheses, our analysis indicates that a group is more likely to stay together when comprised of multiple riders from the same team, indicating that asymmetry in the number of teammates positively affects coordination. Furthermore, our empirical examination of win frequencies aligns with our theoretical expectations. Notably, we find that having a teammate in the first¹⁰ or particularly in the second group increases the win probability of a rider in the first group, highlighting the beneficial impact of teammates within the same group and especially of teammates in the group behind. This latter effect is in line with our theoretical predictions, remarkably robust, and somewhat surprising.

Additional to our previously mentioned contribution to the coopetition literature, we contribute to multiple strands of literature. Firstly, our work adds to the literature on cooperation and social dilemmas, as surveyed in Gorman (2014). Specifically, we provide empirical evidence on equilibrium selection in coordination games involving heterogeneous

⁹Additionally, we collected in-race data of recent races in order to justify our approach of using the results data for our main analyses.

¹⁰It is also important to realize that teammates within groups serve more complicated roles than can be expressed within our model: They might help each other out with supplies if one of them runs out or simply provide psychological relief.

players. Most closely related to us is Brouwer and Potters (2019), who model the coordination problem within the front group of a cycling race as a threshold public goods game, albeit without explicitly modeling the strategies of individual teams. A comprehensive review of the collective action literature with heterogeneity is presented in Gavrillets (2015), who notably demonstrates that the largest contributors to the production of collective goods (in our case, offering slipstream to other group members) are typically group members with the highest stake in the game (in our case, the *strongest* team). Additionally, our work is related to Attanasi et al. (2016) and Heinz and Schumacher (2017), who investigate predictors of efficient coordination among subjects towards group-beneficial outcomes in scenarios where free-riding is possible.

Secondly, we add to the theoretical and empirical literature on contest theory (refer to Corchón and Serena (2016) for an overview). In this context, Münster (2007) offers insights into how players allocate energy in situations involving simultaneous inter- and intra-group competition. This bears resemblance to the scenarios we investigate, except for the fact that his model does not account for individuals being part of teams that may span across groups. For experimental findings, refer to Dechenaux et al. (2015) for a survey. Similar to the approach in Brouwer and Potters (2019), we use cycling races as an instance of a contest in the field that provides valuable data for empirical analysis. While our model aligns with contest dynamics, it diverges from the standard contest framework due to the complexity of the strategic setup of a road cycling race. To our knowledge, we are the first to explore contests where participants (in our case, teams) can simultaneously engage in multiple groups.

Thirdly, our utilization of data from professional road cycling contributes to the literature that leverages sports data to gain economic insights. This approach has a longstanding tradition, as it provides a natural framework for competition within a strictly regulated environment, while simultaneously involving high stakes for all agents (see Bar-Eli et al. (2020)). Extensive overviews on this topic can be found in works such as Szymanski (2003)

and Balafoutas et al. (2019). Game-theoretic analysis plays a dual role in sports economics. On one hand, it aids in understanding how rules impact the incentive structures of players (see, for example, Malueg and Yates (2010) and Krumer and Lechner (2017)). On the other hand, athletes' choices help illuminate and validate equilibrium concepts and behavioral biases. This analytical approach has been famously applied in sports like tennis (Walker and Wooders (2001)) and football (Palacios-Huerta (2003)). However, numerous other sports similarly offer opportunities to empirically understand economic concepts. For instance, Gürtler et al. (2023) utilize data from biathlon races to explore the impact of competition on risk-taking, while Neugart and Richiardi (2013) investigate free-riding tendencies in dynamic team choices within swimming. Cycling has also garnered significant attention in the economics and management literature due to its strategic complexity, as elaborated in Mignot (2016).

The outline of the remaining paper is as follows: Section 4.2 introduces our theoretical model, while Section 4.3 illustrates the main principles by guiding through simple examples. Subsequently, Section 4.4 translates these principles into more general theoretical results. Sections 4.5 and 4.6 are dedicated to developing and executing an empirical strategy to provide evidence for our theoretical results. Finally, Section 4.7 concludes.

4.2 Model

We model situations of interest (the decisive part of a bike race) as a one-shot simultaneous-move game with n players (the teams or team managers). Each player i (she) controls a group of k_i agents (the riders). Rider j of team i is characterized by two non-negative integers: Energy $e_{i,j}^0$ and position $p_{i,j}^0$. The position vector p^0 encodes the riders' relative distances. We call all riders with the same position integer a *group* and all riders with the maximal position integer *the breakaway*. The energy vector characterizes the riders' remaining energy budget. Actions in the game cost a certain amount of energy, and a team's win probability in the sprint is proportional to the remaining energy of their strongest rider

in the breakaway, where we call a rider *stronger* than another if they have a higher energy parameter.

Position updating is not straightforward. It depends on all actions taken in the respective rider's group (see below). Position differences can be interpreted as energy differences required to close the respective gap between riders in absence of free-riding.

4.2.1 Actions and strategies

Each rider can perform up to 4 different actions, which have different costs:

Table 4.1: Actions

Action	Energy Cost	Position Impact	
Rest	0	+0 or +1	Follow pace of the group
Pace	1	+1	Set a steady pace for the group
Mark	1	+0 or +1 or +2	Follow if attacks happen, otherwise follow pace of the group
Attack	2	+2	Attack away from the group

e^0 restricts the action that team i can choose for its rider j , that is,

$$A_{i,j}^0 = \begin{cases} \{R, P, M, A\} & \text{if } e_{i,j}^0 \geq 2 \\ \{R, P, M\} & \text{if } e_{i,j}^0 = 1 \\ \{R\} & \text{if } e_{i,j}^0 = 0. \end{cases}$$

By playing *Attack* (A), riders try to break away from the other group members, so to split up the group. This can be visualized as a small sprint that riders do and comes with the largest energy cost as well as a certain position increase of two units. On the other side of the spectrum, the cheapest action is *Rest* (R), which symbolizes riding in the middle or back of a group. Riders choosing this action save energy, but might still be able to profit from another rider in the group playing *Pace* (P). They follow the pace of the group and will only be left behind if other group member(s) Attack. Choosing *Mark* (M) means being vigilant to another player Attacking: Riders playing M pay an energy cost of

1 to watch out for attacks and thereby making sure that one will not be overtaken by any other rider (neither by riders of the same group nor by riders of a group following behind). If another rider of the group does actually play A , the rider playing M will keep up with that rider, while paying less than the attacker. If no-one Attacks, the rider playing M rides along at the pace of the group at a higher price than required. In this sense, M 's cost is fixed and the positional consequence is uncertain ex-ante. Choosing P instead results in the respective rider dragging the group behind while not following attacks, but mitigating the resulting gap, should an attack occur.¹¹

It might be counterintuitive that P and M are always equally costly, even though M could result in either a sprint or riding slowly. We choose these energy costs for simplicity of the model. Our results are not qualitatively altered by conditioning the energy cost of M on whether there actually is an attack or not, as long as M is always more costly than R and less costly than A . Also, intuitively, M is indeed costly even if no attack occurs because it requires a rider to be in the front of the group (facing wind) and to focus. For a rigorous formulation of the updating rule, see the Appendix.

A team's strategy consists of one action per rider. We denote the strategies as a vector of actions and order this vector by position and, if several riders are at the same position, by effort. For example, the first entry is always the rider of the team closest to the front of the race and if there are two riders of a team in the same group, the first entry refers to the rider with more energy left.

4.2.2 Payoff function

After the game, riders have updated positions and energies encoded in vectors e^1 and p^1 . We model the sprint for the victory as a Tullock contest with each team's strongest rider in the front group (with maximum position) with remaining energy as effort levels. We use the Tullock contest for simplicity of exposition. The only property that the contest

¹¹This can often be seen in cycling races if a favorite has a strong team in the mountains. This team will then be collectively at the front of the peloton, setting a high pace in order to discourage others to Attack.

function must satisfy for the results reported in Section 4.4 is that payoffs are increasing in the energy left after the game.¹² This setup implies that each team's strongest rider in the first group sprints for the win using all remaining energy, and the win probability for that respective sprinter is proportionate to the fraction of the total energy sum of all sprinters. If no member of the front group has any energy left, each team (not rider) wins with equal probability. Formally, equating team i 's utility with their winning probability, this is represented by the following payoff function:

$$u_i = \begin{cases} \frac{\max_{j \in B_i} e_{i,j}^1}{\sum_{k=1}^n \max_{j \in B_k} e_{k,j}^1} & \text{if } \sum_{k=1}^n \max_{j \in B_k} e_{k,j}^1 \neq 0, \\ \frac{1}{|\{k \mid B_k \neq \emptyset\}|} & \text{if } \sum_{k=1}^n \max_{j \in B_k} e_{k,j}^1 = 0, \end{cases}$$

where $B_i = \{1 \leq j \leq k_i \mid p_{i,j}^1 = \max_{(i',j')} p_{i',j'}^1\}$ denotes team i 's riders in the front group after positions and energy levels are updated based on the teams' actions.

Teams indirectly determine their contest effort by selecting their riders' actions within the game. Notably, riders from the same team do not sprint against each other under any circumstances. While this might initially seem counterintuitive, cycling teams typically designate a sprinter while the other riders support their strongest teammate. Our definition of the sprint takes into account that any numerical advantage should have already been utilized earlier, rather than conferring an advantage in the final push to the line. We assume payoffs are structured such that higher remaining energy levels enhance an individual's win probability, rather than explicitly modeling individual sprint capability. This approach is sensible because we explicitly choose to investigate sprints from small groups. Such races are extremely attritional for the members of this group, which may impact individual sprint capabilities severely. Additionally, when a small group of riders finishes together, they typically share similar rider characteristics (otherwise they might not have selected

¹²For instance, we could also add a constant to the remaining energy levels of each rider before computing the payoffs with the Tullock function, which would make sure that each team has a positive probability of winning. However, some of the examples later on are considerably easier to present in the case where riders fully exert themselves (see the explanation under Table 4.2).

into the leading group), which makes individual fatigue a potentially pivotal factor in the sprint to the finish line (instead of some sprint capability score independent of e_j).

4.3 Illustration of main principles

In this section, we use our model to shed light on the strategic intricacies of situations that are frequently observed in real races. In the first two subsections, we informally use examples to illustrate our findings, before we move on to show a general result on the cooperation behavior of one group chasing another.

In the following, we adopt specific conventions. Capitalized verbs refer to the actions by their full names (Attack, Pace, Mark, Rest). We refer to the actions Rest and Mark as *successful free-riding* if they result in a maximally feasible position increase (+1 for R , +2 for M). Subsequently, we illustrate how teams can effectively utilize having multiple riders at the front of the race. We present scenarios as one-shot normal-form games in the following subsections, identifying trembling hand perfect equilibria (THPE) using risk dominance¹³ as a selection criterion in cases of equilibrium multiplicity. Trembling hand perfection rules out Nash equilibria that are not robust to small mistakes, as is to be expected in cycling races. Risk dominance is an empirically proven selection criterion for equilibria in coordination games.¹⁴

This analysis is essentially divided into two parts. Firstly, we show that a group collectively profits from one team having several riders in a group. Counterintuitively, however, this may hurt the team with several riders in the sense that they would prefer the outcome of the situation in which they had only one rider in the group. Given the nature of our model as a simultaneous one-shot game, they can not change this any more at that point. We will later empirically investigate whether teams end up in such an unfavorable situa-

¹³Schmidt et al. (2003) show that changes in risk dominance, unlike changes in payoff dominance, significantly affect play of experimental subjects in symmetric two-player games.

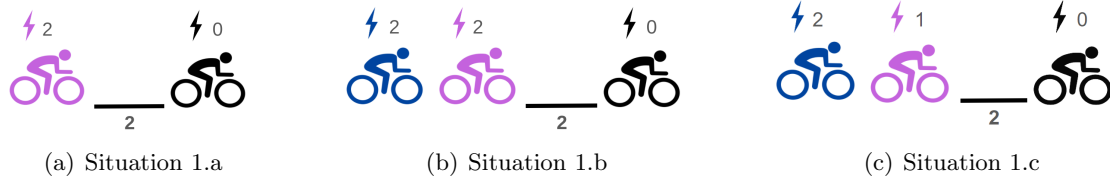
¹⁴See Selten (1975) for trembling hand perfection and Harsanyi and Selten (1988) for risk dominance. Note that payoff-dominance is not applicable in our situations.

tion. Secondly, we show that having riders in two competing groups (one group trying to stay ahead, the other trying to catch up) presents a favorable scenario for a team. In this setup, both riders are likely to free-ride successfully because their respective teammates pose an external threat to everyone in the group except them.

4.3.1 Teammates in a group: How to coordinate a chase

The possibility of drafting makes coordinating intra-group competition in a homogeneous group a chicken game: Everyone desires someone to chase (or pace), but no one wants to assume the role of the designated chaser (or pacer). To illustrate this, consider the following scenario: One rider has invested all their energy earlier in the race to break away and is now 2 position units ahead of a chasing group. They can no longer play anything but R , whereas the chasing group needs a positional increase of 2 in order to retain any chance of winning. Varying the composition of the chasing group affects the qualitative equilibrium outcome.

Figure 4.1: Coordinating a chase (A)



A single chaser with remaining energy of at least 2 (as depicted in Situation 1.a) will always catch up by playing A , as this is clearly the dominant strategy in this case. In a situation like 1.c, where there's an additional chaser unable to catch up independently, the blue rider will still opt to Attack, while the pink rider benefits from Marking, resulting in a win probability of $1/3$ for all three teams. Situation 1.b presents a more intricate scenario, which can be rigorously analyzed by a game matrix like in Table 4.2 below. The corresponding game matrices of all the other situations we discuss in the underlying section

4. Theory and evidence on coopetition in road cycling

are presented in Table 4.8 in the Appendix. The unique THPE of the game in Situation 1.b is highlighted by the red box (omitted strategies are strictly dominated in this instance):

Table 4.2: Situation 1.b - payoff matrix

		Pink Team	
		M	A
Blue Team	M	$0,0$	$1,0$
	A	$0,1$	$\frac{1}{3}, \frac{1}{3}$

If there are two equally strong competing chasers, both with a remaining energy of 2, the solo escapist will win for sure in equilibrium¹⁵, because the homogeneous chasing group struggles to coordinate on who takes the lead in increasing the group's position. This is an example of *coordination failure*. In the following, we refer to a situation as a *coordination problem* if several group members want the group's position vector to increase, but prefer if a rider of another team takes the lead. By taking the lead, we mean that a rider plays Attack (or Pace, depending on the desired position increase). We call a set of actions of group members in a coordination problem a coordination failure if no rider takes the lead. Hence a coordination problem boils down to group members *coordinating* on one rider taking the lead. Note the difference to Situation 1.c, where there are two competing chasers with different remaining energy levels and only one of them is strong enough to close the gap ($e_{i,j} \geq 2$). In such scenario, the stronger rider will close the gap in equilibrium. Consequently, the pink rider profits from being weaker than their blue

¹⁵Note that this example critically depends on the fact that if a rider takes the initiative, he will end up with an energy level of 0 for the ensuing contest, rendering him ex-post indifferent between taking the initiative and resting. If we increase the energy levels of each of the riders in the chasing group to 3, the solo escapist will no longer win for sure. However, as long as both chasers have the same energy left, the trembling hand perfect equilibria of the game (which will then be (M,A) and (A,M)) are symmetric, such that there is no way to select one of the equilibria as the more probable one in the one-shot game. Furthermore, in the (unique) mixed strategy equilibrium, there is always a positive probability of coordination failure, see Proposition 9.

opponent (as observed in Situation 1.c compared to 1.b), based on the following pattern.

Pattern 1. *If equally strong riders compete, coordination failure may occur.*

Now consider two situations where the chasing group is asymmetric and several riders have enough energy to take the lead, like in the Situations 2.a and 2.b below:

Figure 4.2: Coordinating a chase (B)



Note that, in Situation 2.b, the blue team needs to specify two actions for each strategy, one for each rider, with the aforementioned convention that the stronger rider's action is always specified first. We again omit weakly dominated strategies. Note that, if two members of the same team are part of the same group, some of their strategies are weakly dominated by construction - for example, both members of the same team in the same group should never simultaneously choose *A*, as this is dominated by the weaker member opting for *A*, while the stronger one selects *M* (again, refer to the Appendix for the corresponding payoff matrices).

In Situation 2.a, the higher energy level of the pink rider leads to the chasing group coordinating on this rider taking the lead. This coordination succeeds because the pink rider anticipates that the blue rider will refrain from Attacking, so they have to put up with the blue rider free-riding.

In Situation 2.b, a teammate of the blue rider is added to the chasing group. It now consists of one rider of one team and two riders with energy 2 from a competing team. In this scenario, one of the riders from the team with multiple members in the group will Attack and thus allows the rider from the other team to free-ride. The comparison of

Situations 2.a and 2.b with Situation 1.b establishes Pattern 2:

Pattern 2. *Asymmetry in number of team members or rider's strength helps solve coordination problems of groups of riders.*

The mechanism behind this pattern deserves some attention. In order to solve the coordination problem of the group, consensus on who needs to Attack is required. This consensus is established if all riders are aware that one rider has either the most energy or a helper.¹⁶

Comparing Situations 2.a with 2.b reveals another interesting pattern. If the group's strongest rider is not part of the team with multiple group members, this team would prefer to have only their strongest rider in the group. In other words, the win probability for the blue team is higher in Situation 2.a than in Situation 2.b (refer to Section 4.4 for the general formulation), leading to Pattern 3:

Pattern 3. *If a team does not have the strongest rider in a group, it is disadvantageous for this team to add a helper to the group.*

This is somewhat surprising: A team might be better off having only one rider within a group than having two. If in an actual race situation, this means that if a team has the opportunity to place a teammate into the group of their strongest rider (for instance by having a teammate catch up from a group behind or drop back from a group in front), they might not always want to do so. To understand this result intuitively, it is useful to picture the following situation: If two equally strong riders and one very strong rider form a group of three that is under pressure to catch a group further up the road, Pattern 2 (and the explanation below it) predict that the strong rider needs to take the initiative to close the gap. Now consider the scenario that arises if we add a (even weaker) teammate (helper) of one of the weaker riders to the group. This leads to the coordination problem being

¹⁶In actual races, consensus is likely to also be affected by other things like, for instance, beliefs about riders' strengths or riders' ambitions.

solved in a different way: Because the helper can never win the race, he will be required to take the initiative. Consequently, the outcome for the inter-group competition is the same, but the intra-group dynamics change: the strong rider can now free-ride, improving his chances of winning.¹⁷

4.3.2 Teammates across groups: Creating free-riding opportunities

After we have shown that it is not unambiguously good to have more riders in the same group for a team, we will now turn to illustrating why it is never a bad thing to have several riders across groups. For this, consider the following two situations:

Figure 4.3: Teammates across groups (A)



In Situation 3.a, when two riders from opposing teams are not contending with a rival group, it's evident that both have an expected probability of $1/2$ of winning the race before competing in the final period. Situation 3.b adds a strong rider from the blue team as (part of) a chasing group to the scenario.¹⁸

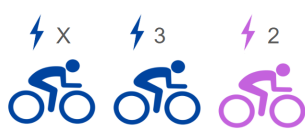
The addition of the chaser strictly improves the winning chances of the blue team. Instead of winning with equal probability (Situation 3.a), the blue chaser *forces* (in equi-

¹⁷It is important to realize that we do not argue that teammates are only useful if they are supporting the strongest rider in the group. Having a teammate gives a team more strategic freedom (especially at earlier stages in the race) and may be the only option to close a gap at all. We just point out that in many setups of the decisive part of the race, it might be better to assign a teammate to a competing group if that option is feasible.

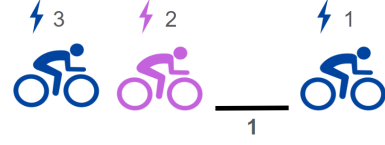
¹⁸The corresponding payoff matrices are again presented in the Appendix. In Situation 3.b, it suffices to examine the strategic interaction between the two riders in the front group, as the rider in the chasing group will end up Attacking.

librium) the pink rider to Attack and thereby allows the blue rider of the front group to benefit from free-riding, leading to a winning probability of $2/3$ for the blue team. What's particularly intriguing is that the chaser never wins in equilibrium; rather, it's their mere presence that influences the outcomes. We observe that adding a teammate to a group behind the front group can yield a positive impact on the win probability of the respective rider within the front group.

Figure 4.4: Teammates across groups (B)



(a) Situation 4.a



(b) Situation 4.b

Let's now examine a similar scenario where there is a teammate up front instead of a teammate behind. We compare Situation 4.a, where there's no teammate up front but instead a teammate within the group, with Situation 4.b. In the latter case, a rider of a chasing group has a teammate riding solo up front; we refer to such a rider as a *Satellite* (for the corresponding payoff matrices again see Table 4.8 in the Appendix).

When having a rider up front, the blue team will instruct the Satellite to play Pace in order to remain ahead of the chasers. This amplifies the energy advantage of the blue rider in Group 2, as it allows him to conserve energy by drafting behind the pink rider who is now forced to Attack if they want to catch up with the Satellite. In this extreme scenario, the blue team wins with certainty. This implies that regardless of the variable energy level x in Situation 4.a, where the pink team's expected equilibrium payoff is positive,¹⁹ the blue team would always prefer Situation 4.b, emphasizing the advantage of initiating a

¹⁹In Situation 4.a, the blue team mixes between $R|M$ and $M|A$ (the action of the stronger rider is mentioned first) while the pink team mixes between R and M . The resulting expected equilibrium payoff is positive for the pink team. As a consequence, the blue team prefers Situation 4.b over 4.a for all x .

solo breakaway early in the race.

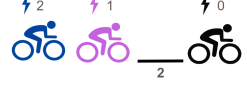
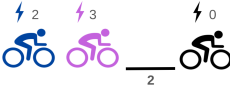
Comparing Situation 3.a with 3.b and 4.a with 4.b illustrates how the blue team *strategically* benefits from having two riders across two groups, leading to the following pattern:

Pattern 4. *Having riders in different groups leads to a strategic advantage for a team in the coordination dynamics in all of the respective groups.*

Pattern 4 embodies the central finding of our paper: *the strategic benefit from diversification*. In the above situations, diversification refers to a team placing their riders into more than one group. This strategy enables teams to leverage free-riding opportunities within these groups. The presence of teammates in other groups lowers the pressure to take the lead, as teammates serve as credible outside options.

To recap all the scenarios we have discussed above, consider the following table:

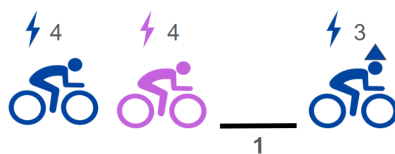
Table 4.3: Summary of possible setups in the last period

 Situation 1.a: Payoff = $(\frac{1}{2}, \frac{1}{2})$	 Situation 1.b: Payoff = $(1, 0, 0)$	 Situation 1.c: Payoff = $(\frac{1}{3}, \frac{1}{3}, \frac{1}{3})$
 Situation 2.a: Payoff = $(0, \frac{1}{2}, \frac{1}{2})$	 Situation 2.b: Payoff = $(0, \frac{1}{3}, \frac{2}{3})$	
 Situation 3.a: Exp. payoff = $(\frac{1}{2}, \frac{1}{2})$	 Situation 3.b: Payoff = $(\frac{2}{3}, \frac{1}{3})$	
 Situation 4.a: Payoff = $(< 1, > 0)$	 Situation 4.b: Payoff = $(1, 0)$	

Comparing Situation 1.a, 1.b, and Situation 1.c illustrates how symmetric groups struggle to coordinate, as indicated by Pattern 1. In Situation 2.a and 2.b, we observe two different pathways through which breaking the symmetry leads to successful coordination of the group, denoted by Pattern 2. Comparing Situations 2.a and 2.b also illustrates Pattern 3: it might be disadvantageous to have a helper in a group. Situation 3 and 4 illustrate the strategic benefits of having riders in several groups. A team's weaker rider in the front of the race profits from the threat generated by having a strong teammate chasing. A similar effect can also help the chasing rider if they have an opponent to free-ride on within their group. Overall, this analysis underscores the strategic preference for teams to deploy riders across various groups rather than placing them within the same group.

We will now show, rather informally, how this principle can influence decision-making earlier in the race. Imagine the teams play two periods of the positioning game instead of one, with the setup in the penultimate period as depicted in Situation 5.a. Depending on the riders' actions, we might observe the emergence of either Situation 5.b or 5.c from the starting point of 5.a.

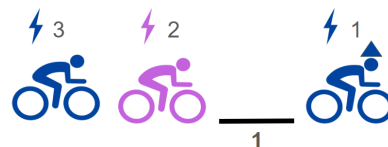
Figure 4.5: A hypothetical penultimate period



(a) Situation 5.a: Chasers play (M, A)



(b) Situation 5.b: After Satellite (with hat) played Pace



(c) Situation 5.c: After Satellite (with hat) played Attack

It is important to recognize that the pink team in Situation 5.a faces pressure to play

Attack (formally, they would opt for this in each subgame-perfect equilibrium) to avoid the Satellite's certain win up front. The blue chasing rider will then play Mark. With this in mind, the blue team has two options for their Satellite rider: either allow the chasing group to catch up so that the Satellite can assist their teammate within the group (Situation 5.b), or maintain the Satellite's lead (Situation 5.c).²⁰

Situation 5.c mirrors Situation 4.b, guaranteeing a definite win for the blue team. In contrast, Situation 5.b introduces a possibility, however small, of the pink team winning. This underscores the blue team's preference for their Satellite rider to maintain their distance from the chasing group, highlighting the strategic advantage of strategically distributing riders among various groups and maintaining this arrangement for as long as feasible.

4.4 General theoretical results

In this subsection, we address the dynamics of group coordination and the related problem of successful free-riding within our model in more generality. The following two propositions specifically imply Pattern 1 to Pattern 4 as stated in the previous section. We provide easy-to-understand versions of our propositions in this section. For formal versions and proofs, we refer to the Appendix.

The following proposition formalizes Pattern 1, 2, and 3.

Proposition 9. *Consider a set of teams represented in a group. Without loss of generality, we focus on teams that each prefer their strongest rider to Attack over no member of the group to Attack. In other words, we focus on teams that play a coordination game amongst each other on who has to use some rider to Attack and who may free-ride.²¹ Then in any THPE of the resulting coordination game of these teams, the following statements are true for the riders represented in that set:*

²⁰The corresponding actions of the Satellite rider are Pace, in order to fall back into their teammate's group (Situation 5.b), and Attack, in order to stay up front (Situation 5.c).

²¹There may be teams that could free-ride but could not afford to have their strongest rider attack, which makes them exempt from any strategic considerations.

4. Theory and evidence on coopetition in road cycling

If at least one team has two riders with at least two energy units remaining, then

- (a) *One rider with at least two energy units Attacks, and all other riders successfully free-ride (Mark).*

If no rider has a teammate with at least two energy units remaining,²² there are several equilibria, which satisfy:

- (b) *Each mixed equilibrium has a positive probability of coordination failure.*
(c) *In the risk dominant equilibrium,²³ the strongest rider attacks.*

Proof. See Appendix. □

The rationale behind Proposition 1 is straightforward. In a race scenario involving multiple groups, each group comprising riders who prefer to maintain a high pace faces a coordination challenge: Who will take the lead and endure the wind resistance to allow others to draft behind? Among these riders benefiting from maintaining speed, there exists a hierarchy determining who must undertake this costly task. If a team possesses multiple riders capable of playing Attack, other teams can insist that they sacrifice one of their weaker riders for this purpose. Our proposition demonstrates that each team with such a rider will indeed Attack, thereby eliminating the possibility of coordination failure. If no team enjoys this privileged situation, any scenario where exactly one rider bridges the gap represents a pure Nash equilibrium. Part (b) illustrates the potential for coordination failure in equilibrium. Lastly, part (c) indicates that, in the risk dominant equilibrium, the rider with the most remaining energy will be compelled to close the gap. Part (c) relies on the assumption of perfect information. In actual race situations, one can often observe riders feign weakness for this very reason. In the conclusion, we discuss the appropriateness of this assumption and possible relaxations.

Proposition 1 offers a formal framework to elucidate the phenomena outlined in Patterns 1 through 3. For Pattern 1, taking (b) and (c) together pins down our understanding of

²²Then the teams play a coordination game on whose *strongest* rider has to Attack and who may free-ride. We can assume w.l.o.g. that each team has their strongest rider as the only rider, which means that each team only has *A* and *M* as undominated strategies.

²³See Harsanyi and Selten (1988).

groups failing to coordinate. Risk dominance as an equilibrium selection criterion applies if there is a unique strongest rider. If there is no such strongest rider, there is also no unique risk dominant equilibrium in the coordination game.²⁴ Then, part (b) points out that if players mix between taking the initiative and attempting to free-ride, any equilibrium has a positive probability of coordination failure occurring. Note that (b) is also true if there is a unique risk dominant equilibrium. We merely point out that our model collapses to an asymmetric-payoff coordination game in some cases. There, it is a reasonable and empirically verified assumption (see Schmidt et al. (2003) and Straub (1995)) that players end up in the risk dominant equilibrium.

Parts (a) and (c) explain the mechanisms driving Pattern 2 and Pattern 3 in a straightforward way. When certain riders possess teammates or are stronger than the other group members, their teams bear the responsibility of pushing the group along by Attacking, thereby solving the group's coordination problem.

To gain further insight into Pattern 4, we require another proposition. This pattern specifically refers to scenarios where one team has multiple riders spread across different groups (which may or may not occur within the framework of Proposition 1). As explained in Section 4.3.2, the value of teammates in competing groups is created by those teammates constituting a credible outside option and thereby facilitating opportunities for free-riding.

Proposition 10. *Placing a rider's teammate into a different group weakly increases the respective rider's probability of successful free-riding in each THPE.*

Proof. See Appendix. □

This clearly implies Pattern 4 because a positive probability of successful free-riding is a desirable property.

²⁴Then, teams are symmetric in the sense that any team in the relevant coordination game attains some payoff p if they take the initiative, and some payoff q if they free-ride successfully, with p and q equal across teams.

4.5 Data and empirical strategy

We proceed by examining empirical evidence supporting our stylized Patterns 1 - 4, drawing on data from actual professional road cycling races. We exclusively consider individual stages of multi-day stage races in the main text of the paper but demonstrate in the Appendix that our results are qualitatively similar if using data from one day races within the same time period. We introduce and empirically assess hypotheses derived from our theoretical results on the coordination of groups and the strategic advantages of having teammates - in terms of increasing the probability of being at the front of the race and winning, respectively. To this end, we use data on the top 15 finishers of highest-level road cycling races since 1981. We observe the names of these riders, their teams, and the respective riders' gaps (in seconds) to the winning rider.

In order to find evidence for our theoretically derived stylized patterns, we would ideally need a dataset containing the individual energy levels of all riders in the front groups at the decisive moment of a road cycling race. Clearly, this is not feasible. Firstly, not even the riders in the race are aware of the energy levels of their competitors. We try to circumvent this difficulty by only differentiating between riders that are commonly believed to have high energy levels remaining and those that don't, using the same proxy that the riders in the race are likely to use: The past success of individual riders. Specifically, we indicate riders that were amongst the most successful riders of the last season as *Stars*. Secondly, the process of grouping riders is essential. We employ a five-second threshold to determine group composition; if the time gap between two consecutive riders at the finish is below 5 seconds, they are considered part of the same group. Thirdly, there is no extensive database of in-race statistics such as group compositions and gaps between groups, which means that we do not have information about the setup at the front of the race at the decisive moments.

Our theoretical framework offers insights into riders' behavior in the final stages of

a race, yet the only large and available dataset consists of race results. We therefore additionally collected data on the group compositions at 1000 meters before the finish line for all races used in our main analysis since the year 2020.²⁵ As shown in the 4.C.2, our main result(s) will hold independently of whether we use the in-race data or the results data. Thus, we make use of the large dataset on the results to analyze the properties of *successful* riders in specific race situations, about which our stylized patterns make specific claims. These claims are stated in the empirical hypotheses below, mainly addressing the following two key aspects.

We aim to understand which group characteristics facilitate coordination, as outlined in Pattern 1 and Pattern 2. Successful coordination entails group members fulfilling their roles harmoniously, leading to enhanced group cohesion. To investigate this, we contrast groups of riders finishing together with batches of riders finishing in close proximity to one another, examining the differences in riders' characteristics between these two situations.

Additionally, we strive to examine the advantages derived from having a teammate in different groups, as elucidated in Pattern 3 and Pattern 4. To achieve this, we conduct various linear regressions using the race results data. These regressions assess whether a rider's win probability or likelihood of finishing in the leading group is influenced by a teammate's position, such as being in the same group or in the group behind. Our primary theoretical result suggests that having a teammate in a group behind positively impacts a rider's win probability. Although the strategic benefits of extensive free-riding options occur before the finish line, riders with a teammate behind should still be more likely to be observed as victorious at the finish line than riders without a teammate around.

²⁵Video material of in-race data is publicly available only for races that took place in recent years. We were able to collect, by hand, in-race data for all 101 races of the seasons between 2020 and 2023 that are part of our main analysis.

4.5.1 Race results data

We scraped placement and time-gap data from the website ProCyclingStats.com (www.procyclingstats.com). We use results data from 1981 to 2023 on stages of multi-day stage races of the highest division of professional road cycling.²⁶ We collect all available data of the three grand tours, which all last three weeks: Tour de France, Giro d’Italia, and Vuelta à Espana. Also, we use the results of the seven best-known one-week stage races.²⁷ As a robustness check, we repeat our analyses for the most famous one-day races with data again ranging from 1981 to 2023 (see Appendix).²⁸ For all of these races, we save the names, teams and time gaps to the winner of the top 15 finishers.

The focus on stage races is motivated by a key characteristic inherent to these events. In nearly every stage of a stage race, the occurrence of an early breakaway is a prevalent phenomenon (see Brouwer and Potters (2019)). This predictable race structure unfolds with remarkable consistency: shortly after the race begins, a group of riders breaks away from the main pack, known as the *peloton*,²⁹ and gains distance ahead. Subsequently, until the race’s final stages, minimal significant action takes place, and the gap between the breakaway and the peloton remains relatively stable. Typically, the peloton possesses the collective strength to reel in the early breakaway, provided they initiate their pursuit early enough.

One-day races are more attritional than stages of stage races and winning them comes with high prize money and reputation. For this reason, the early breakaway almost never wins in one-day races. At the same time, fewer riders finish the race, because time gaps don’t matter (as opposed to stage races), which means the groups chasing one another at the end of the race are comparatively small. Still, strategic timing of attacks plays a role

²⁶The organization of these races has changed over the years, nowadays they are all part of the UCI World Tour.

²⁷These one-week stage races are: Criterium du Dauphiné, Tour de Romandie, Itzulia Basque Country, Tour de Pologne, Tour de Suisse, Paris-Nice, and Tirreno Adriatico.

²⁸These one-day races are: Il Lombardia, Tour of Flanders, Paris-Roubaix, Milano-Sanremo, Liège-Bastogne-Liège, Gent-Wevelgem, La Flèche Wallone, and the San Sebastián Classic.

²⁹The peloton is cycling lingo and (loosely) defined as the largest group of the most “relevant” riders.

in winning these races and a single rider can hold off a group if group members do not cooperate well.³⁰

4.5.2 Data processing

To conduct our analyses, we initially identified races where the battle for victory unfolded among small clusters of riders. We operationally define a group as comprising riders who finish within a five-second window of one another. In other words, if the time gap between two consecutive riders falls below 5 seconds, they are considered part of the same group. If the time gap between a rider and the one ahead exceeds 5 seconds, the former is deemed to belong to a separate group.³¹ Decreasing this threshold does not alter the qualitative findings of our analyses (refer to the Appendix for a rerun of our analyses with the most extreme case, a 1 second threshold). We discard all races in which the first two groups both consist of riders of only one team (i.e., there is no intra-group competition) and all races where the last rider of the third group places 15th or worse.³² This leaves us with 729 stages.³³

4.5.3 Individual rider data

To control for the strength of individual riders, we use a Star-dummy, based on ProCyclingStats' individual rider scores (PCS-scores) from the season previous to the respective

³⁰Despite these facts, we can recreate some of our results on stage races on the dataset on one-day races from the same period, as can be seen in the Appendix. It is very important to note that the number of one-day races that feature groups that are large enough to conduct our analyses is quite small, which means that we cannot use our full set of controls on this dataset, which is why we did not include these analyses in the main paper.

³¹We choose this in such a way that the final Tullock contest does not influence group composition: The potential gap created by the final sprint (the Tullock contest) is very unlikely to exceed 5 seconds.

³²In larger groups, it is hard to justify the game-theoretic formulation of the situation in which every team considers possible strategies of every other team's riders in the group. Also note that we need three complete groups of riders in order to consider teammate-behind-effects of riders that are part of the second group.

³³We ended up discarding 2988 stages of the 3717 stages we have scraped initially.

race.³⁴ A Star is a rider that in the previous season has reached a PCS-score that puts him in the top 20%. These scores are calculated by summing the points earned by a rider across all races they participated in during the respective calendar year. A rider scores points for placing well in races, with more coveted races awarding the top riders more points. We rely on the previous season's PCS-scores to mitigate endogeneity issues.³⁵

In many situations, the categorical Star-dummy is sufficiently informative about the pecking order of a group to make a statement about our theoretical predictions, for instance if there is a single rider classified as a Star in a group. Also, we must note that Stars, by definition, are the best finishers of the previous season, even (or especially) when exhausted. This should effectively determine the beliefs of other non-Star group members about that riders energy left.³⁶

4.5.4 Group characteristics

We define the following variables:

- **Star:** “Star” riders are riders which ranked in the top 20% of the last season's score ranking. Changing the percentile does not lead to qualitative changes in the results (see Appendix).³⁷
- **Stronger Rider Around:** Dummy. 1 if a member of the first two groups is a Star

³⁴PCS-scores are available on ProCyclingStats' website: <https://www.procyclingstats.com/rankings/me/season-individual>.

³⁵It is important to note that a rider with more points than another is not necessarily the all-around better rider. This is due to several reasons. Firstly, there is a difference in riding for a stage win or a classification win in a stage race. Secondly, superstar riders pick specific target races for their season, but also participate in so-called tune-up races, where they choose not to compete. Lastly, rider characteristics matter a lot. A great climber stands no chance in a flat sprint, but might still be identified as a Star when looking at generalized rider rankings. Some riders may also accumulate points simply by participating in more races than others. For these reasons, we use a categorical Star-dummy instead of using the raw PCS-score as an ordinal metric of rider strength.

³⁶We must note that, given that non-Star group members believe a certain Star rider to win the race even when their “energy battery” is low, forcing the respective Star rider to spend effort is not beneficial anymore. Instead, the non-Star group members might increasingly concentrate on the race against the other non-Star members for second place.

³⁷We have also run the regressions with an “Underdog” dummy, indicating no significant effect on the results. There, “Underdogs” were defined as riders being ranked in the bottom 20% of the last season's score ranking.

and from another team, while the respective rider is not a Star.

- **Stronger Rider in Group:** Dummy. 1 if a rider finishing in the same group is a Star and from another team, while the respective rider is not a Star.
- **Helper:** Dummy. 1 if there is a teammate finishing behind but in the same group.
- **Teammate behind:** Dummy. 1 if at least one rider finishing in the group behind is a teammate.

Summary statistics on these variables can be found in the Appendix. It is noteworthy that Groups 1 and 3 are significantly (on 1% - level, determined by a Wilcoxon-rank-sum test) smaller than Group 2. There is no significant difference between Groups 1 and 3. Stars occur more often in Groups 1 or 2 than in Group 3.³⁸

4.5.5 Hypotheses

Given the aforementioned data, we can translate our stylized patterns from the above section into testable hypotheses. Both Pattern 1 and Pattern 2 propose that groups of riders are more prone to coordination failures when group members exhibit symmetry. Within our theoretical framework, such coordination failures may result in groups fragmenting or being unable to catch up with another leading group. Consequently, the following (testable) hypothesis emerges:

Hypothesis 1. *A winning group arriving together is more likely to be asymmetric.*

To test this, we compare the characteristics of groups of riders finishing together with those of batches of riders finishing in close proximity. If Hypothesis 1 is accurate, we anticipate a higher probability of observing asymmetry, such as the presence of teammates or singled-out Stars, in the former case. This asymmetry fosters consensus among group members regarding their roles, thereby enhancing coordination within the group during the race, and thus leading to an increased likelihood to reach the finish as a group.

³⁸All the mentioned differences are significant on the 1% - level, determined by a chi-squared test of proportions.

Pattern 4 addresses the strategic benefit for a team of having riders placed in different groups. Such diversification helps in the coordination dynamics within each of the groups and theoretically results in riders being able to save energy for the final sprint (the final Tullock contest in our model). In the results data, we thus expect to observe the following:

Hypothesis 2. *Having a teammate in the group behind positively impacts win probability.*³⁹

On the contrary, as per our model, having a teammate within a group could potentially be disadvantageous. This effect hinges significantly on the rider's strength compared to the group members' strength, as outlined in Pattern 3 and in the following hypothesis:

Hypothesis 3. *The effect of having a teammate in the same group positively impacts win probability for the group's strongest rider(s) and negatively impacts win probability for riders that are weaker than other group member(s).*

To test Hypotheses 2 and 3, we conduct fixed-effects regressions using riders' properties on a win-dummy, and similarly on a first-group-dummy.⁴⁰ Interpreting the coefficients of these regressions provides comparative-statics insights into win probabilities. Hypothesis 2 predicts a positive impact from the Teammate-behind-dummy, while Hypothesis 3 suggests a negative interaction effect between the Stronger-Rider-in-Group-dummy and the Helper-dummy.

Note that all the hypotheses operate under the assumption that riders who performed well in the previous season (referred to as Stars) are presumed to have larger energy reserves. If this assumption seems circular, it at least does not detract from the interpretation of our results. In our regressions, the Star-dummy variable can also be viewed as a control for publicly available information on race-winning characteristics.

³⁹Note that we cannot measure the impact on win probability of a teammate in front.

⁴⁰The first-group-dummy indicates whether the rider is part of the winning group at the finish.

4.6 Results

We now discuss the results of the empirical analyses outlined in the previous section.

4.6.1 Comparing groups

Let's begin by examining the factors that contribute to effective group coordination, particularly in terms of staying together. Nearly half of the races in our dataset (347 out of 729) are categorized as “solo wins”.⁴¹ This means that the first and second places are separated by at least 5 seconds. It's quite perplexing that in so many races, a single rider manages to maintain a lead over pursuing groups. One explanation to this puzzle might be individual strength. One rider might just be so much stronger than the others that they can keep a group at distance, even if the respective group cooperates well.

Another explanation might be the frequent occurrence of coordination failure in the pursuing Group 2 as discussed before. According to our Hypothesis 1, such failures to cooperate should be more likely to occur in symmetric groups. For this, we identify the following two kind of groups: A front group of 3 to 6 riders, versus a Group 2 which loses against a solo rider by at least 10 seconds (see Table 4.4) of similar size.⁴² We then compare the symmetry-characteristics we have available across these groups. If a team comprises more than one rider, we consider it asymmetric in team strength, while the presence of a Star denotes asymmetry in individual strength (see the discussion in Section 4.5.5). Both factors are expected to enhance coordination and are thus more likely to be observed in groups that finish at the forefront.

We find weak confirmatory evidence for this: At least one Helper is present in only 14% of the groups that lose against a solo rider while Stars are present in 52% of the respective

⁴¹That is although many solo wins are excluded when we filter out races where both first groups consist of only one team. Hence, the proportion of solo wins (on total wins of “not too large groups”) could even be larger.

⁴²We throw out mountain top finishes as there cooperation failure is most likely not to play a decisive role. Then, both groups end up with an average group size of 3.8 riders. We have 125 groups which come in first and 84 that lose against a solo rider.

groups. In contrast, groups, that do not allow for a solo win, include at least one Helper or one Star with probabilities 23% and 62%, respectively. So groups that do not lose against a solo rider are indeed more asymmetric than the ones that have failed to catch up with a solo rider (though differences are not significant).⁴³

Table 4.4: Asymmetry in losing versus winning groups

	group losing against solo	winning group
Helper is present	14%	23%
Star is present	52%	62%

In the left column of Table 4.5, we investigate the same issue in a regression framework, which allows us to include additional controls. The regression considers front groups and groups behind a solo as independent draws. The endogenous variable is a dummy that equals 1 if the group has finished first and equals 0 if the group has finished behind a solo rider. The dependent variables are group characteristics and their estimated coefficients measure the impact of the respective characteristic on the “success probability” of the group, or, in other words, on the probability of not having lost against a solo rider but having finished first. A positive coefficient indicates that groups that finish first display a higher propensity toward this characteristic than groups that fail to catch a solo. We once again are unable to find significant effects.

In the right column of Table 4.5, the analysis is similar. We now compare front groups (again focusing on groups with 3 to 6 riders) with sets of riders that have also finished up front but are not part of a group, i.e., that are isolated. The endogenous variable is a dummy that equals 1 if and only if the riders are part of a front group, and 0 if they are part of a set of riders that finish first but not together as a group. Regarding asymmetry in individual strength, we once again rely on the presence of a Star as our best proxy

⁴³Note that the differences between the two kind of groups are not significant (Chi-squared test). Also, an OLS regression, with being in the winning group as the dependent variable, does not allow us to conclude a significant impact of asymmetry (see Table 4.5).

Table 4.5: Linear probability model: Being part of a winning group (with 3 to 6 riders)

	versus group behind Solo winner	versus riders not finishing as group
Intercept	0.567*** (0.145)	0.142** (0.055)
Star in group exists	0.055 (0.079)	0.049 (0.041)
Helper in group exists	0.103 (0.095)	0.690*** (0.098)
Observations	209	364
R^2	0.019	0.164
Adjusted R^2	-0.015	0.148
F Statistic	0.570 (df=7)	9.97*** (df=7)

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variables are dummies, indicating whether group finishes first.

We additionally control for the number of teams per group and stage type.

but do not find a significant effect. Regarding asymmetry in team strength, we observe that asymmetry in teammates significantly and positively impacts the probability that the set of riders has reached the finish as a group, rather than having finished as isolated riders. This suggests that the presence of at least one rider with a teammate might indeed enhance group cooperation, thereby increasing the probability of group cohesion and thus supporting Hypothesis 1.

4.6.2 Impact of group characteristics on win probabilities

Let us turn to discussing evidence for Hypotheses 2 and 3. We run fixed-effects regressions with two different endogenous variables: A dummy of finishing in the first group (coming close to a win) and a win-dummy. In the main text, we present OLS regressions; logit regressions as robustness checks are in the Appendix.

Who makes the first group?

Here, our dependent variable is a dummy variable, indicating whether the rider in question is part of the first group. The left column of Table 4.6 includes all riders finishing in the first two groups; the right column all riders finishing in the first three groups.

We observe that the presence of a stronger rider has a negative impact on the probability of being in the first group. Consequently, being a Star and having no Star present in the first two groups appears to have a positive effect. In addition, conditional on being in one of the first two groups, having a teammate in the group behind has a significantly positive effect.⁴⁴ This dummy is not included in the right column because we only look at data on the first three groups for all races.

Table 4.6: Linear probability model: Finishing in Group 1

	G1 if in G1/G2	G1 if in G1/G2/G3
Intercept	0.467*** (0.072)	0.395*** (0.066)
Stronger rider around	-0.172*** (0.021)	-0.158*** (0.017)
Teammate behind	0.120*** (0.024)	
Observations	3523	4805
R^2	0.270	0.219
Adjusted R^2	0.257	0.209
F Statistic	20.4*** (df=63)	21.5*** (df=62)

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variables are dummies, indicating whether riders are part of Group 1.

We additionally control for year, race, stage type, gap sizes between groups, and group sizes.

The effect of a teammate behind is not immediately obvious. There are several potential mechanisms through which the leading rider could have benefited. The teammate might have been helpful within the same group and then dropped back after “completing their

⁴⁴Note that we control for the number of riders in each group in the upcoming analyses. Thus, the larger mean in Group 2 than in Group 1 does not distort our “teammate-behind effect”.

work”. However, our in-race data suggests that this happens only quite rarely, at least on the last 1000 meters.⁴⁵ Also, a teammate of a rider in Group 1 might have caused coordination problems in the group behind by refusing to cooperate with the others, making it less likely that the pursuing group catches up. Thirdly, there is the effect that is suggested by our model: having a teammate behind might lead to a strategic benefit to the rider in the front group, facilitating to free-ride and to save effort. Ultimately, all these effects support Hypothesis 2.

Who wins out of the first group?

Now, only riders that are part of the first group are included in the analysis. All races where a solo rider wins are discarded.⁴⁶ Our dependent variable is a dummy variable specifying whether the rider in question has won the race.

The first two columns indicate a positive impact on the likelihood of winning the race when a teammate is present in either the same group or, particularly, in the group behind. As mentioned earlier, this supports Hypothesis 2. In the right column of Table 4.7, we randomly assign riders to “teams”⁴⁸ in order to check whether some of the discussed effects exist by construction. In particular, Helpers finish by definition after another member of the team. This means that such team member has finished quite well, increasing their win probability by construction. Consequently, the positive effect of having an Helper seems to (fully) stem from how we defined Helpers in the first place. Also, the interaction term between the Stronger-Rider-in-Group-dummy and the Helper-dummy can thus not be used to confirm or disprove Hypothesis 3. In contrast, the “teammate-behind effect” appears to

⁴⁵In only 2 out of 16 cases the winner’s teammate-behind dummy is different at the finish line compared to the 1000 meter mark in our in-race dataset (see 4.C.2).

⁴⁶Winning groups of only one rider must be excluded because then all group members (which is only the solo rider) win the race with probability one.

⁴⁷By group size we mean the number of different teams that are part of the respective group. So adding a Helper to a group does not change the group size.

⁴⁸We assign each rider with equal probability to a number between 1 and 22 (which is the number of teams that typically compete). Riders with the same number are defined as “hypothetical teammates”.

Table 4.7: Linear probability model: Winning the race from Group 1

Hypothetical teams	NO	NO	YES
Intercept	0.480*** (0.168)	0.476*** (0.168)	0.561*** (0.213)
Stronger rider in group	-0.041 (0.031)	-0.032 (0.030)	-0.028 (0.032)
Helper	0.122* (0.074)	0.172*** (0.058)	0.232*** (0.056)
Stronger rider in group x Helper	0.126 (0.115)		
Teammate behind	0.139*** (0.044)	0.138*** (0.044)	0.031 (0.056)
Observations	1212	1212	1090
R^2	0.097	0.096	0.098
Adjusted R^2	0.048	0.048	0.044
F Statistic	1.97*** (df=63)	1.98*** (df=62)	1.81*** (df=62)

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variables are dummies, indicating whether riders have won.

We additionally control for year, race, stage type, gap sizes between groups, and group sizes.⁴⁷

In the hypothetical teams treatment we randomly assign riders to teams.

be driven by an actual in-race (strategic) benefit.

The failure of confirming Hypothesis 3 might also be due to the limitations of our dataset. The above regressions do not necessarily imply that Helpers are not more advantageous to riders with no stronger rider around, such as Star riders. This is because an effective Helper for a Star rider would typically not be part of the winning group at the finish line.⁴⁹ Instead, they would exit the winning group after having completed their role.⁵⁰ Unfortunately, our results data lacks the capability to capture such Helper dynamics causally.

⁴⁹Unless they were a Satellite rider being caught just before the finish line. In this particular case, they did not serve as an in-group Helper during the race.

⁵⁰Dropping out of the winning group seems to be more likely for Helpers of Stars as putting all one's eggs into one basket makes much more sense if the team has a Star sprinting for the win.

Despite the dataset’s limitations, it is noteworthy that our key finding, the positive “teammate-behind effect”, persists across all our analyses. Robustness checks in the Appendix include variations in the definitions of Stars as well as how and “when” groups are defined. Our regression results exhibit resilience to these variations, reinforcing the robustness of our findings. The robustness of our main finding is particularly confirmed by the positive and significant effect of having a teammate in the group behind at the 1000 meter mark on the respective rider’s win probability (see 4.C.2).

4.7 Conclusion

In this article, we have modeled the strategic considerations that govern interactions of small groups of riders in road cycling races, framing it as a normal-form game. We examine the factors that encourage coordination within these groups and assess the added advantage of incorporating teammates into competing groups to enhance individual teams’ winning prospects. Our findings shed light on the pivotal role of establishing consensus on who needs to contribute the most to a public good in resolving the social dilemmas inherent in inter-group competition during cycling races.

Within our model, we unveil a crucial mechanism: In scenarios where groups of riders compete, teams with multiple riders in a single group will always contribute to the inter-group conflict by “sacrificing” their weaker riders first. Conversely, when such an option is unavailable due to the absence of teammates, the onus of leading the inter-group conflict typically falls on the strongest rider, measured by their energy reserves. This mechanism yields several non-trivial implications for a team’s utility: Firstly, the presence of a teammate alongside the team’s strongest rider may not always confer an advantage, as this teammate is most beneficial to the strongest rider within the group, who might belong to another team. This occurs because the presence of such an helper, regardless of their team affiliation, reduces the pressure on the strongest rider to lead within the group, potentially enabling them to free-ride when they otherwise couldn’t.

Secondly, we observe that adding teammates to a competing group consistently proves advantageous. These additional riders serve as an outside threat to all non-teammates within the group, increasing the pressure on these riders to take the lead. If the strongest rider of a group possesses a teammate in a chasing group, the pressure on him to take the lead dissipates because their incentives change, altering other teams' beliefs as well. Consequently, placing a teammate in a competing group comes with a strategic benefit: It allows for more extensive free-riding. We can conclude that having teammates as outside options serves a similar purpose as feigning weakness on race day. It's worth noting that our theoretical findings hinge on the assumption of perfect information; in a framework of private information, the ability to free-ride would be contingent upon other riders' beliefs regarding the relative remaining strength of members within a given group. The assumption is similar to assuming that riders have common beliefs about their opponents' strengths. We believe that this assumption is quite appropriate in the context of cycling races because energy at the end of the race is strongly correlated with how successful a rider has been in previous races of similar characteristics. Road cyclists race frequently together and hence know their opponents' strengths and weaknesses well. Also, we analyze the strategic setup late in a race, when teams had ample opportunity to test the condition of riders of other teams through attacks earlier in the day. Extending the model to include this explicitly, in the form of multiple periods and heterogeneous beliefs would be an interesting extension. In such a framework, behavior early in the race would send signals about individual energy levels and early attacks by teammates could be used as a screening device.

In our empirical analysis, we examine data spanning over four decades of results in major professional stage races and find confirmatory evidence for the stylized patterns elaborated above. Firstly, we find evidence for our theoretical hypothesis that in-group asymmetry solves the coopetition dilemma. The presence of teammates enhances the cohesion of groups, thereby reducing the likelihood of defeat against a solo rider.⁵¹ Fur-

⁵¹Note that we can only establish significance for the effect on group cohesion but not on the likelihood of losing against a solo rider.

thermore, we establish that having a teammate in the group behind positively impacts the likelihood of a rider ending up in the first group of a race and, given the rider is part of this first group, increases their probability of winning the race. Notably, these two effects are highly significant and robust, align in the same direction, and thus “add up”. Consequently, a team’s overall win probability appears to be much higher when the team has “diversified”, i.e., has placed riders into different groups.⁵²

Applied to professional cycling, the findings suggest that cycling teams benefit from assembling a strong group of riders for a race, rather than relying solely on a single strong leader. We find that “utilizing” a teammate to catch a group benefits all members of that group, regardless of team affiliations. Consequently, the marginal utility of adding a teammate to a rider’s group is in many cases lower than the marginal utility of adding a teammate to a competing group where the teammate represents an exogenous threat. This tendency can indeed be observed in the professional cycling world, where the practice of lining up multiple leaders has become increasingly prevalent, as discussed in the case studies provided in Appendix A.⁵³

While our model is tailored to the free-riding dynamics of road cycling races for empirical validation, the core insights extend to other scenarios. More broadly, we provide fundamental (theoretical) insights into the interaction between free-riding and diversification in the context of a competing volunteer’s dilemma: The benefit gained from diversifying between bets on mutually exclusive events goes beyond merely reducing outcome uncertainty. To illustrate this strategic benefit of diversification, let us return to the examples from the introduction. The investor with hotels on both islands A and B can free-ride on her competitors’ investments into the public good on each island because she is diversified.

⁵²Subsequent empirical investigations could utilize rider GPS data or employing increasingly accessible image analysis techniques on TV broadcasts to extract detailed in-race (meta-)data concerning group composition at various points throughout the race, facilitating a more careful analysis of the described dynamics.

⁵³The sport has very recently evolved into a more tactically sophisticated realm since the media outcry following the release of the Netflix documentary “The Least Expected Day”, which has exposed the tactical shortcomings of certain cycling teams.

The PhD Student, applying for the same faculty position as her co-author, benefits from having two active projects. She thereby not only benefits from diversification itself⁵⁴ but also gains a strategic advantage over the other Student. By creating an outside option, she forces her co-author to take the lead, allowing herself to benefit from increased free-riding opportunities.

Similar considerations apply to other situations, such as patent races or competition for research grants. The same logic also extends to the financing of startups,⁵⁵ to political competition,⁵⁶ and to infrastructure projects.⁵⁷ All of these scenarios require careful individual analysis due to their specific incentive structures. However, they are all subject to the same stylized results: When some form of social dilemma needs to be resolved, such as a public goods game, asymmetric resource distribution increases the likelihood of a group coordinating by naturally establishing a consensus on the allocation of contributions. For individual actors, being resourceful in one way or another comes at the cost of increased pressure to be the main contributor, whether through personal strength or by having helpers within the same group. Within a broader context of competing public goods games, this pressure can be alleviated by diversifying resources across multiple competing projects. Such diversification strategies allow the party to exert less effort compared to non-diversified actors: Investing in multiple startups within the same sector provides an excuse to abstain from subsequent investment rounds. Holding stakes in opposing outcomes of political decisions helps avoid involvement in contentious debates. Engaging in multiple competing infrastructure projects enables free-riding across each endeavor.

⁵⁴Diversification often reduces the risk of total failure or loss and increases the chance of any success. It is particularly beneficial to risk-averse individuals.

⁵⁵Having teammates who can be placed in competing groups is analogous to allocating effort or money to competing projects.

⁵⁶We refer to a coopetition problem where different parties must collaborate within a coalition, where free-riding is possible, while also cooperating to win against a competing group, the opposition. Here, diversification — in the sense of “flirting” with the opposition — might lead to strategic benefits within the coalition.

⁵⁷A more comprehensive discussion of this topic is provided in the introduction, where the coopetition problem within (air)ports and tourist destinations is briefly discussed.

An in-depth analysis of the latter scenario could be of significant interest to the industrial organization literature. When evaluating a merger between two firms and assessing the market power of the (potentially) newly formed entity, the regulator must consider that the now larger firm is also more diversified. This diversification might lead to additional strategic benefits in the form of free-riding opportunities, potentially giving the new firm greater market power than a straightforward assessment might suggest. Notably, we are unaware of any prior analyses on these strategic advantages stemming from free-riding options for diversified parties, thus leaving this area very much open for future theoretical and empirical research.

Appendix

4.A Case study: The strategic benefits of having multiple leaders in road cycling races

The tactics employed by cycling teams undergo periodical changes, like in most sports, as teams react to changes other teams make. However, certain aspects of bike races appear to remain constant. Typically, in most races, an early breakaway gets a small advantage early in the day, although there is virtually no chance for that breakaway to outlast the peloton later if one or more teams decide to *control the race*.

Controlling the race means having riders ride at the front of the peloton for most of the day to keep the gap to the breakaway constant, then increase the pace later in the race to outright catch the breakaway. Teams adopt this strategy when they aim to secure the win and are not satisfied with their prospects within the breakaway, such as when they lack representation in that group. In a flat race, most of the controlling comes down to the final kilometers of the race, when the teams that want to catch the breakaway form so-called *leadout trains*, as can be seen in Figure 4.6.

In the early 2010s, the British cycling team Sky invested considerable amounts of money into the analysis of all aspects of road racing with the sole purpose of winning the Tour de France with a British rider for the first time. Among their tactical innovations was adapting sprint leadouts for mountainous races, leading to the concept of the “Sky Train” or “Mountain Train” (see Figure 4.6). This strategy aimed to effectively control mountain stages by organizing a line of strong climbers, with the team captain positioned behind the last helper, at the front of the peloton during long climbs (lasting around thirty to forty minutes). This approach helped stabilize the race by discouraging attacks and maintaining a steady gap to breakaway groups, increasing the likelihood of catching them before the

Figure 4.6: Controlling the race



(a) Controlling a flat race

(b) Team Sky's mountain train

finish line. One of the main results of our paper states that controlling a mountain stage, however, is only helpful, if the hard pace benefits your leader more than the others.

4.A.1 Who controls a race?

Frequently, multiple teams may have motives to take control of the race. However, the practical implementation of this strategy can be disadvantageous for the team conducting it since riders at the front of the peloton can sustain high speeds for only a limited duration before fatigue sets in.

Our strategic analysis focuses on the coordination problem that the teams with an incentive to chase face because of this. Who controls the race? The intuitive answer suggests that the most pressure to do so will be put on the strongest team. Formalizing this is not straightforward, however. Our paper examines the role of strength along two different dimensions: Having more helpers or having a stronger captain. We find that teams with an incentive to chase should use their helpers relatively liberally, but once only team leaders are left, the one most likely to win in a direct sprint will be forced to do the hard work - unless that team has an outside option, i.e. a promising rider in the breakaway! That “unless” is what we want to focus on in the following because it is a factor teams can

influence beforehand, e.g. by actively trying to put a rider in the breakaway or even earlier, in the selection of their race roster. As we will expand on now, in many instances, including several leaders with different specialities (for instance breakaway specialists and sprinters) is advantageous for a team. Even having multiple co-leaders of different capabilities in the same speciality can prove useful.

4.A.2 The strategic benefit of multiple leaders

One recent example of stellar team strategy in a one-day race was the 2024 edition of “Milano-San Remo”. Team Alpecin-Deceuninck nominated two leaders: Breakaway specialist Mathieu van der Poel and sprint specialist Jasper Philipsen. Van der Poel managed to join a small breakaway late in the race, at this point the clear favorite to win the race. Meanwhile, this group was chased by a group containing Philipsen as the fastest sprinter.

If van der Poel were not present in the breakaway, all riders of the chasing group would want Philipsen to ride at the front to catch the breakaway because they most likely would beat all the others in a sprint. Similarly, if Philipsen weren’t chasing, van der Poel would be the one pressured to lead the breakaway in order to stay away from the chasing group. However, in reality, with both riders in their respective positions, they both could free-ride within their groups. Why? Van der Poel was indifferent to whether the breakaway was caught because if it was, his teammate Philipsen stood a good chance of winning. Similarly, Philipsen was unconcerned about the breakaway being caught because van der Poel would probably win if it stayed away. One of the events had to happen, of course. Eventually, van der Poel’s group did get caught. When that happened, the optimal strategies changed, and Team Alpecin-Deceuninck was prepared! It was now Mathieu van der Poel who immediately started riding at the front. This is due to the fact that Philipsen was now the clear favorite to win the final sprint of the new, larger front group, so they were responsible for making sure that they did not get caught by other groups of riders behind them. Having van der Poel as a helper prevented him from needing to be the one riding at

the front by himself. Now guess who won the race? A very much rested Jasper Philipsen.

4.A.3 The crucial role of beliefs

In the 2020 Tour de France, 21-year old Tadej Pogačar made his debut in the biggest stage race in the world with a team of helpers that were completely unable to provide him with assistance in the mountains. However, they were not the main favourite to win the race. That role fell to his compatriot Primož Roglič, who arrived with a team that was perfectly capable of providing him with a mountain train in the decisive stages. In all of these stages, Roglič's team (Jumbo Visma) controlled the race, and every time Pogačar followed their train but never attempted to take the race lead from Roglič. This was until the second last stage⁵⁸ of that Tour de France, an individual time trial up a mountain.⁵⁹ Only on that day, when team tactics had no impact at all, did it become obvious that Pogačar, not Roglič, was the strongest climber in the race. Roglič had built an advantage of 57 seconds over the previous nineteen race days, but lost close to two minutes on the day. It remains unclear whether Pogačar and his team knew at any point of the race that they had the strongest rider but from how they behaved over the three weeks in July 2020, it is obvious that Jumbo Visma never suspected it.⁶⁰ Otherwise, they should not have controlled the mountain stages the way they did.

4.A.4 How to use multiple leaders in a stage race

We have seen how Alpecin-Deceuninck used two leaders with different skillsets to win Milano-San Remo above. Reading how Roglič lost the Tour de France 2020, you might ask: “If Pogačar was the strongest rider, how could Roglič's team have defeated him

⁵⁸Since a few decades there is a “gentleman's agreement” among riders for the very last stage that ends in Paris: the general classification is not fought over. Consequently, the penultimate stage is the riders' last chance to attack the leader.

⁵⁹In an individual time trial, the riders do not start all at once but separately in reverse ranking order of the general classification, making free-riding pretty much impossible.

⁶⁰Jumbo Visma's director had stated the day before Stage 20 that they were “95 per cent certain to win the Tour”.

Figure 4.7: How (not) to use your teammates



(a) Pogačar (in white) behind Jumbo Visma's mountain train

(b) Pogačar (in yellow) against Roglič and Vingegaard (both in brown)

anyway?” Our paper provides the answer: by forcing Pogačar to exert himself by chasing down attacks. How this might look in detail became clear two years later, when Pogačar arrived at the Tour de France with a now much stronger team. Ranked as the best rider in the world after his dominant victory in the Tour de France 2021, Pogačar again faced his main rival, Primož Roglič, who now had the support of a co-captain, Danish climber Jonas Vingegaard (who had finished second only to Pogačar the previous year, after Roglič had crashed early in the race). Jumbo Visma designated both Vingegaard and Roglič as equal leaders and utilized their mountain train for both of them.

On stage 11 of that Tour, Jumbo Visma made their bet for the lead on the penultimate mountain of the day, the Col du Galibier. They alternated attacks between Roglič and Vingegaard, prompting Pogačar to close the gap to either attacker repeatedly. After Pogačar caught up, they immediately slowed down, allowing their other leader to follow Pogačar without sprinting all-out every time. That way, they made Pogačar so tired that when they attacked with Vingegaard on the final climb, Pogačar finally cracked and lost several minutes. Vingegaard won the Tour that year, genuinely looking stronger than Pogačar also later in the race. However, Jumbo's strategic brilliance lay in their willing-

ness to sacrifice Vingegaard's ambition for Roglič's. Had Pogačar not followed Roglič on any occasion on the Galibier, the latter might have ridden away to win the Tour instead.

Jumbo Visma have since stuck largely to the multiple-leader strategy and took this to the extreme when they won the Tour of Spain in 2023 with Sepp Kuss, their third-strongest rider. Kuss had been let go in a breakaway in the first of three weeks of racing, gaining a large lead on all other teams' leaders. Jumbo Visma used Vingegaard and Roglič to put the other teams under pressure on all subsequent mountain stages but ended up winning the race with Kuss. Notably, Kuss struggled to follow Vingegaard and Roglič at times, and his odds to win the race before the first stage were a staggering 325:1.

The lessons drawn from these cases and scenarios highlight the value of having multiple leaders when managed strategically. The advantage gained from employing several leaders exceeds the benefits of mere diversification. This strategic benefit arises from a simple principle, which our paper is the first to point out: distributing riders across various groups can create opportunities for free-riding in each of the groups.

4.B Theory

4.B.1 Position updating

Given actions a and positions p^0 , the updated position vector p^1 is constructed as follows:

$$p_{i,j}^1 = \begin{cases} p_{i,j}^0 + 2 & \text{if } \begin{cases} a_{i,j}^0 = A, \text{ or} \\ a_{i,j}^0 = M \wedge \exists(i', j') : p_{i',j'}^0 = p_{i,j}^0 \wedge a_{i',j'}^0 = A. \end{cases} \\ p_{i,j}^0 + 1 & \text{if } \begin{cases} a_{i,j}^0 = P, \text{ or} \\ a_{i,j}^0 \in \{R, M\} \wedge \exists(i', j') : p_{i',j'}^0 = p_{i,j}^0 \wedge a_{i',j'}^0 = P, \text{ or} \\ a_{i,j}^0 = M \wedge \exists(i', j') : p_{i',j'}^0 = p_{i,j}^0 - 1 \wedge a_{i',j'}^0 = A. \end{cases} \\ p_{i,j}^0 & \text{if } a_{i,j}^0 \in \{R, M\} \wedge \nexists(i', j') : p_{i',j'}^0 = p_{i,j}^0 \wedge a_{i',j'}^0 = P. \end{cases}$$

4.B.2 Payoff matrices

All payoff matrices are presented in Table 4.8.

Note the following:

- In Situation 3.a, there is no Nash-equilibrium in pure strategies. In the THPE both players mix between R, M and A. The equilibrium payoff is $(\frac{1}{2}, \frac{1}{2})$.
- In Situation 4.a, we assume that $x > 3$. For the blue team, the action $M|A$ means that the rider stronger rider (the one with x energy units remaining) plays Mark and the weaker rider Attacks. Again, there is no Nash equilibrium in pure strategies. In the THPE the blue team mixes between $R|M$ and $M|A$ and the pink team mixes between R and M.

4. Theory and evidence on coopetition in road cycling

Table 4.8: Payoff matrices of the discussed situations

Situation 1.a			Situation 1.b			Situation 1.c				
Pink			Pink			Pink				
Black		M	A	Blue		M	A	Blue		M
	R	1, 0	$\frac{1}{2}, \frac{1}{2}$		M	$\frac{0}{0}, \frac{0}{0}$	1, 0		M	0, 0
Situation 2.a			Situation 2.b							
Pink			Pink							
Blue		M	A	Blue		M	A			
	M	0, 0	$\frac{1}{2}, \frac{1}{2}$		$M M$	0, 0	$\frac{1}{2}, \frac{1}{2}$			
Situation 3.a			Situation 3.b							
Pink			Pink							
Blue		R	M	A	Blue		P	M	A	
	R	$\frac{1}{2}, \frac{1}{2}$	$\frac{3}{5}, \frac{2}{5}$	0, 1		R	$\frac{5}{7}, \frac{2}{7}$	$\frac{5}{7}, \frac{2}{7}$	0, 1	
	M	$\frac{2}{5}, \frac{3}{5}$	$\frac{1}{2}, \frac{1}{2}$	$\frac{2}{3}, \frac{1}{3}$		M	$\frac{5}{7}, \frac{2}{7}$	$\frac{5}{7}, \frac{2}{7}$	$\frac{2}{3}, \frac{1}{3}$	
Situation 4.a			Situation 4.b							
Pink			Pink							
Blue		R	M	Blue		P	A			
	$R M$	$\frac{x}{x+2}, \frac{2}{x+2}$	$\frac{x}{x+1}, \frac{1}{x+1}$		$P M$	$\frac{1}{0}, \frac{0}{0}$	$\frac{1}{0}, \frac{0}{0}$			
	$R A$	1, 0	$\frac{1}{2}, \frac{1}{2}$		$P R$	1, 0	$\frac{1}{2}, \frac{1}{2}$			

4.B.3 Proof of Proposition 1

In the following, we order e_i^t , p_i^t and s_i w.l.o.g. by magnitude of the components of e_i^t . Note that the game is by construction a coordination game in which each Nash Equilibrium s^* satisfies $s_{i,j} = A$ for some (i, j) and $s_{i',1} = M$ for all $i' \neq i$ (this is then the best response for the designated sprinter of team i').

- (a) Let i denote a team with $e_{i,2} \geq 2$. Remember that we assume that each team sometimes prefers $s_{i,1} = A$ over $s_{i,1} = M$ (namely if nobody plays A). It is clear that $s_{i,1} = M$ and $s_{i,2} = A$ leads to a strictly higher payoff for team i than any strategy tuple with $s_{i,1} = A$, which means that the strategy $s_i = (M|A|...)$ is weakly dominant. Because weakly dominated strategies can never be played in THPE, (a) is true. Given the strategy of team i in (a), A is clearly never a best response to this, which shows that all other riders Mark.
- (b) Because the setup is that of a coordination game, for each team, there is a *strict* equilibrium in which one of the riders of this team Attacks (and no other rider Attacks) and a strict equilibrium in which no rider of the team Attacks (and some other rider from another team Attacks), there must be an equilibrium in which each team places a probability strictly between 0 and 1 on Attacking and not Attacking, respectively. Hence, in such a mixed strategy equilibrium, there is a positive probability of no rider Attacking.
- (c) W.l.o.g., assume that each team has only one rider and denote $e_i = e_{i,1}$. Let s be the team with the strongest rider and $\bar{e} = \sum_i e_i$. By the Nash-Product theorem in Harsanyi and Selten (1988), we need to show that

$$\forall j \neq s : \left(0 - \frac{e_s - 2}{\bar{e} - 3}\right) \prod_{i \neq s} \left(\frac{e_i - 2}{\bar{e} - 4} - \frac{e_i - 1}{\bar{e} - 3}\right) > \left(0 - \frac{e_j - 2}{\bar{e} - 4}\right) \prod_{i \neq j} \left(\frac{e_i - 2}{\bar{e} - 4} - \frac{e_i - 1}{\bar{e} - 3}\right).$$

4. Theory and evidence on coopetition in road cycling

See Example 2 for the two player case. Continuing with the general case, dividing by $\prod_{i \neq s,j} \left(\frac{e_i-2}{\bar{e}-4} - \frac{e_i-1}{\bar{e}-3} \right)$ yields

$$\left(\frac{e_j-2}{\bar{e}-4} - \frac{e_j-1}{\bar{e}-3} \right) \left(0 - \frac{e_s-2}{\bar{e}-3} \right) > \left(0 - \frac{e_j-2}{\bar{e}-3} \right) \left(\frac{e_s-2}{\bar{e}-4} - \frac{e_s-1}{\bar{e}-3} \right).$$

This indeed holds because the inequality boils down to $(e_s - 2)^2 > (e_j - 2)^2$ and because $e_s > e_j$ is true by assumption.

Example 2. Suppose there are two riders in a group with different levels of energy (strength) and both riders prefer to Attack over no member of the group to Attack. Then, in the risk dominant equilibrium, the stronger rider Attacks.

Proof. Suppose there are two riders playing a coordination game on who Attacks. The stronger rider (pink) has an energy level of e_s whereas the weaker rider (blue) has one of e_w , with $e_s > e_w$ and $\bar{e} = e_s + e_w$. This corresponds to the following game matrix with the two pure strategy equilibria inside the red boxes.

	A	M
A	$\frac{e_w-2}{\bar{e}-4}, \frac{e_s-2}{\bar{e}-4}$	$\frac{e_w-2}{\bar{e}-3}, \frac{e_s-1}{\bar{e}-3}$
M	$\frac{e_w-1}{\bar{e}-3}, \frac{e_s-2}{\bar{e}-3}$	0,0

Here, the equilibrium where the strong (pink) rider Attacks is the risk dominant one if and only if the following holds (the product of deviation losses must be highest⁶¹ in the risk dominant equilibrium, see Harsanyi and Selten (1988)):

$$\left(\frac{e_w-2}{\bar{e}-4} - \frac{e_w-1}{\bar{e}-3} \right) \left(0 - \frac{e_s-2}{\bar{e}-3} \right) > \left(0 - \frac{e_w-2}{\bar{e}-3} \right) \left(\frac{e_s-2}{\bar{e}-4} - \frac{e_s-1}{\bar{e}-3} \right).$$

⁶¹We can interpret the product of deviation losses at an equilibrium as a measure of collective reluctance to deviate from that equilibrium.

This indeed holds because the inequality boils down to $(e_S - 2)^2 > (e_W - 2)^2$ and because $e_S > e_W$ is true by assumption. $\square$

4.B.4 Proof of Proposition 2

Adding a member of team i to a group that previously had no rider of group i creates an outside option in the following way:

- If team i has a rider in the front group and a rider is added to the second group, the win probability for team i in the case of coordination failure in the front group is now (weakly) higher. This means that team i 's riders in the front group can play A with lower probability.
- If team i has a rider in the second group and a rider is added to the front group, the win probability for team i in the case of coordination failure in the second group is now (weakly) higher. This means that team i 's riders in the second group can play A with lower probability.

Given that team i 's riders play A with lower probability, the other teams react (in equilibrium) by playing Attack more often. This further increases the win probability of team i 's rider of the initial group (the rider that obtains a new teammate in another group) because they benefit from more extensive free-riding options.

4.C Empirical results

4.C.1 Summary statistics

Table 4.9: Summary statistics of non-dummies

	Group 1 size	Group 2 size	Group 3 size	Gap between Groups 1 and 2	Gap between Groups 2 and 3
mean	2.26	3.16	2.36	40.7	33.3
std	1.91	2.27	1.97	60.6	69.7
min	1	1	1	5	5
50%	2	2	1	22	14
max	12	12	11	853	1155

Table 4.10: Mean occurrence of dummies

	Star	Stronger rider in group	Helper in group	Teammates behind
Group 1	0.284	0.262	0.051	0.122
Group 2	0.269	0.351	0.066	0.093
Group 3	0.193	0.271	0.053	
Overall	0.251	0.301	0.058	0.108

4.C.2 In-race data

In addition to the results data, we collected data on the group compositions when the first group reaches the 1000-meter-to-go mark (this is easily visible, because there is a red flag at this mark) before the finish line for all races used for our regressions (i.e., races that met the qualifying criteria discussed in the empirical section) since the year 2020,⁶² leading to a subset of 101 races. Because this data was collected by hand using TV broadcasts, the group definition is slightly different: We document riders that visibly ride together in a group in the conventional sense of the word. We find that the group setup is not generally

⁶²We could only make use of recent races where video material is still publicly available.

stable. In only 53% of the races there are no changes at all in the first three groups. In contrast, the teammate-behind dummy is quite persistent. There are only two races where the winning rider has a teammate in the group behind at the finish but not at the 1000-meter-to-go mark (out of the total of 16 races where the winner has a teammate in the group behind at the finish). However, importantly, as reported in Tables 4.11 and 4.12, there are no qualitative differences in our two main regressions based on whether we use the group compositions at the finish or 1000 meters before. While the teammate-behind-dummy is significant in Table 4.6, which uses results data from 1980 onwards, it is not significant using results data from 2020 onwards (like in Table 4.11). Re-running our win-regression with a teammate-behind dummy that indicates whether the respective rider had a teammate in the group behind at the 1000-meter-to-go mark (“in-race-teammate-behind dummy”) leads to the same qualitative results as with our “results-teammate-behind dummy” (see Table 4.12).

Table 4.11: Linear probability model: Finishing in Group 1 - in-race data

In-race data	NO	YES
Intercept	0.524*** (0.078)	0.528*** (0.078)
Stronger rider around	-0.146** (0.058)	-0.151** (0.058)
Teammate behind	0.082 (0.066)	0.023 (0.059)
Observations	480	480
R^2	0.295	0.293
Adjusted R^2	0.280	0.278
F Statistic	19.6*** (df=10)	19.4*** (df=10)

Note:

*p<0.1; **p<0.05; ***p<0.01

We include all riders that are part of Group 1 or 2 at the finish.

The endogenous variables are dummies, indicating whether riders are part of Group 1.

We additionally control for year, gap sizes between groups, and group sizes.

We only make use of races that took place in the years between 2020 and 2023.

In the in-race data treatment we look at groups at 1000 meters before the finish.

Table 4.12: Linear probability model: Winning the race from Group 1 - in-race data

In-race data	NO	YES
Intercept	0.522*** (0.118)	0.543*** (0.120)
Stronger rider in group	-0.141* (0.081)	-0.141* (0.081)
Helper	0.176 (0.225)	0.072 (0.135)
Teammate behind	0.261** (0.116)	0.262** (0.115)
Observations	178	178
R^2	0.126	0.126
Adjusted R^2	0.079	0.079
F Statistic	2.69*** (df=9)	2.69*** (df=9)

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variables are dummies, indicating whether riders have won.

We additionally control for year, gap sizes between groups, and group sizes.

We only make use of races that took place in the years between 2020 and 2023.

In the in-race data treatment we look at groups at 1000 meters before the finish.

4.C.3 Additional analyses

Robustness of results: The definition of stars

Recall that in each season, we categorize “Star” riders as those who achieved a top 20% score in the previous season. To check the robustness of our results, Stars are defined as riders placed in the top 10% of the previous season, in the following tables. Despite this difference in definition, our regression tables demonstrate that the overall trends in our results remain consistent. One notable change is the significant negative effect of a “Stronger Rider in Group” on win probability. Specifically, being identified as a Star or having no Star present in one’s winning group positively impacts a rider’s chances of winning (see Table 4.14). However, the majority of effects remain largely unchanged. Especially, the positive influence of having a teammate in the group behind remains significant and maintains its

magnitude.

Table 4.13: Linear probability model: Finishing in Group 1 - fewer Stars

	G1 if in G1/G2	G1 if in G1/G2/G3
Intercept	0.450*** (0.073)	0.376*** (0.066)
Stronger rider around	-0.153*** (0.024)	-0.137*** (0.020)
Teammate behind	0.121*** (0.024)	
Observations	3523	4805
R^2	0.265	0.213
Adjusted R^2	0.251	0.203
F Statistic	19.8*** (df=63)	20.7*** (df=62)

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variables are dummies, indicating whether riders are part of Group 1.
We additionally control for year, race, stage type, gap sizes between groups, and group sizes.

Table 4.14: Linear probability model: Winning the race from Group 1 - fewer Stars

Hypothetical teams	NO	NO	YES
Intercept	0.477*** (0.168)	0.477*** (0.168)	0.562*** (0.214)
Stronger rider in group	-0.064* (0.034)	-0.057 (0.032)	-0.053 (0.036)
Helper	0.140* (0.071)	0.176*** (0.058)	0.160*** (0.053)
Stronger rider in group x Helper	0.104 (0.121)		
Teammate behind	0.139*** (0.044)	0.140*** (0.044)	-0.028 (0.054)
Observations	1212	1212	1061
R^2	0.099	0.098	0.096
Adjusted R^2	0.049	0.051	0.039
F Statistic	1.99*** (df=63)	2.01*** (df=62)	1.70*** (df=62)

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variables are dummies, indicating whether riders have won.

We additionally control for year, race, stage type, gap sizes between groups, and group sizes.

In the hypothetical teams treatment we randomly assign riders to teams.

Robustness of results: The definition of groups

In our main analysis we define a rider to be in the same group as the rider in front of him if the gap between the two riders is below 5 seconds (gap threshold). If the gap to the rider in front is 5 or more seconds then the respective rider is defined to be in a new (higher) group. The following tables show how our main regression results depend on how we define groups. Here, in the “smaller groups setup” the gap threshold is set to 1 second (see Tables 4.15 and 4.16). The results do not change.

Table 4.15: Linear probability model: Finishing in Group 1 - smaller groups

	G1 if in G1/G2	G1 if in G1/G2/G3
Intercept	0.463*** (0.068)	0.386*** (0.062)
Stronger rider around	-0.209*** (0.023)	-0.193*** (0.018)
Teammate behind	0.134*** (0.027)	
Observations	3064	4119
R^2	0.273	0.212
Adjusted R^2	0.258	0.200
F Statistic	17.9*** (df=63)	17.6*** (df=62)

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variables are dummies, indicating whether riders are part of Group 1.
We additionally control for year, race, stage type, gap sizes between groups, and group sizes.

Table 4.16: Linear probability model: Winning the race from Group 1 - smaller groups

Hypothetical teams	NO	NO	YES
Intercept	0.564*** (0.137)	0.563*** (0.137)	0.616*** (0.149)
Stronger rider in group	-0.061 (0.034)	-0.055* (0.033)	-0.050 (0.037)
Helper	0.075 (0.086)	0.119* (0.067)	0.109* (0.060)
Stronger rider in group x Helper	0.107 (0.131)		
Teammate behind	0.163*** (0.050)	0.162*** (0.050)	-0.101 (0.067)
Observations	1061	1061	923
R^2	0.100	0.100	0.097
Adjusted R^2	0.044	0.045	0.033
F Statistic	1.79*** (df=62)	1.81*** (df=61)	1.52** (df=61)

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variables are dummies, indicating whether riders have won.

We additionally control for year,⁶³ race, stage type, gap sizes between groups, and group sizes.

In the hypothetical teams treatment we randomly assign riders to teams.

Hypothetical teammates

We assign each rider with equal probability to a number between 1 and 22 (which is the number of teams that typically compete). Riders with the same number are defined as “hypothetical teammates”.

⁶³We exclude the dummy for the year 1988 due to the lack of data for the respective year.

Table 4.17: Linear probability model: Winning the race from Group 1 - continued

Hypothetical teams	NO	YES
Intercept	0.480*** (0.168)	0.618*** (0.183)
Stronger rider in group	-0.041 (0.031)	-0.032 (0.033)
Helper	0.122* (0.074)	0.247*** (0.076)
Stronger rider in group x Helper	0.126 (0.115)	0.018 (0.124)
Teammate behind	0.139*** (0.044)	-0.039 (0.053)
Observations	1212	1090
R^2	0.097	0.098
Adjusted R^2	0.048	0.046
F Statistic	1.97*** (df=63)	1.88*** (df=63)

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variables are dummies, indicating whether riders have won.

We additionally control for year, race, stage type, gap sizes between groups, and group sizes.

In the hypothetical teams treatment we randomly assign riders to teams.

4.C.4 Logistic regressions

Table 4.18: Logistic probability model: Finishing in Group 1

	G1 if in G1/G2	G1 if in G1/G2/G3
Intercept	-0.233 (0.394)	-0.321 (0.363)
Stronger rider around	-1.09*** (0.129)	-1.02*** (0.111)
Teammate behind	0.642*** (0.129)	
Observations	3523	4805
Pseudo R^2	0.234	0.186

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variables are dummies, indicating whether riders are part of Group 1. We additionally control for year, race, stage type, gap sizes between groups, and group sizes.

Table 4.19: Logistic probability model: Winning the race from Group 1

Hypothetical teams	NO	NO	YES
Intercept	0.204 (0.797)	0.181 (0.795)	0.737 (0.752)
Stronger rider in group	-0.175 (0.160)	-0.125 (0.154)	-0.113 (0.158)
Helper	0.643* (0.359)	0.898*** (0.274)	1.10*** (0.284)
Stronger rider in group x Helper	0.631 (0.547)		
Teammate behind	0.668*** (0.211)	0.559*** (0.202)	0.000 (0.243)
Observations	1212	1212	1129
Pseudo R^2	0.089	0.088	0.080

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variables are dummies, indicating whether riders have won.

We additionally control for year, race, stage type, gap sizes between groups, and group sizes.

In the hypothetical teams treatment we randomly assign riders to teams.

4.C.5 One-day races

Summary statistics

Table 4.20: Summary statistics of non-dummies

	Group 1 size	Group 2 size	Group 3 size	Gap between Groups 1 and 2	Gap between Groups 2 and 3
mean	2.18	3.48	2.92	50.8	46.5
std	1.58	2.54	2.29	49.4	64.7
min	1	1	1	5	5
50%	2	3	2	28	23
max	10	12	11	219	408

Table 4.21: Mean occurrence of dummies

	Star	Stronger rider in group	Helper in group	Teammates behind
Group 1	0.323	0.288	0.038	0.165
Group 2	0.227	0.454	0.072	0.126
Group 3	0.138	0.325	0.057	
Overall	0.221	0.368	0.059	0.149

Regressions

Table 4.22: Linear probability model: Finishing in Group 1 - one-day races

	G1 if in G1/G2	G1 if in G1/G2/G3
Intercept	0.463*** (0.077)	0.315*** (0.063)
Stronger rider around	-0.168*** (0.044)	-0.183*** (0.034)
Teammate behind	0.159*** (0.052)	
Observations	593	837
R^2	0.265	0.202
Adjusted R^2	0.249	0.191
F Statistic	16.1*** (df=13)	17.4*** (df=12)

Note: *p<0.1; **p<0.05; ***p<0.01
The endogenous variables are dummies, indicating whether riders are part of Group 1.
We additionally control for race, gap sizes between groups, and group sizes.

Table 4.23: Linear probability model: Winning the race from Group 1 - one-day races

Hypothetical teams	NO	NO	YES
Intercept	0.696*** (0.135)	0.700*** (0.135)	0.690*** (0.135)
Stronger rider in group	-0.227*** (0.072)	-0.220*** (0.071)	-0.221*** (0.075)
Helper	-0.105 (0.468)	0.165 (0.181)	0.202* (0.122)
Stronger rider in group x Helper	0.317 (0.506)		
Teammate behind	-0.241** (0.102)	-0.242** (0.102)	-0.199 (0.132)
Observations	194	194	178
R^2	0.138	0.137	0.139
Adjusted R^2	0.081	0.084	0.082
F Statistic	2.42*** (df=12)	2.62*** (df=11)	2.43*** (df=11)

Note:

*p<0.1; **p<0.05; ***p<0.01

The endogenous variables are dummies, indicating whether riders have won.

We additionally control for race, gap sizes between groups, and group sizes.

In the hypothetical teams treatment we randomly assign riders to teams.

Bibliography

- Abadie, A., Athey, S., Imbens, G. W., and Wooldridge, J. M. (2023). When should you adjust standard errors for clustering? *The Quarterly Journal of Economics*, 138(1):1–35.
- Abreu, D. and Gul, F. (2000). Bargaining and reputation. *Econometrica*, 68(1):85–117.
- Agranov, M., Eraslan, H., and Tergiman, C. (2022). Bargaining in the shadow of uncertainty. Technical report, National Bureau of Economic Research.
- Agranov, M. and Tergiman, C. (2014). Communication in multilateral bargaining. *Journal of Public Economics*, 118:75–85.
- Agranov, M. and Tergiman, C. (2019). Communication in bargaining games with unanimity. *Experimental Economics*, 22:350–368.
- Attanasi, G., Hopfensitz, A., Lorini, E., and Moisan, F. (2016). Social connectedness improves co-ordination on individually costly, efficient outcomes. *European Economic Review*, 90:86–106.
- Balafoutas, L., Chowdhury, S. M., and Plessner, H. (2019). Applications of sports data to study decision making. *Journal of Economic Psychology*, 75:102153.
- Bar-Eli, M., Krumer, A., and Morgulev, E. (2020). Ask not what economics can do for sports - ask what sports can do for economics. *Journal of Behavioral and Experimental Economics*, 89:101597.
- Baranski, A. and Morton, R. (2022). The determinants of multilateral bargaining: A comprehensive analysis of baron and ferejohn majoritarian bargaining experiments. *Experimental Economics*, 25(4):1079–1108.

BIBLIOGRAPHY

- Baron, D. and Kalai, E. (1993). The simplest equilibrium of a majority-rule division game. *Journal of Economic Theory*, 61(2):290–301.
- Baron, D. P. and Ferejohn, J. A. (1989). Bargaining in legislatures. *American political science review*, 83(4):1181–1206.
- Boles, T., Croson, R., and Murnighan, K. (2000). Deception and retribution in repeated ultimatum bargaining. *Organizational behavior and human decision processes*, 83(2):235–259.
- Bouncken, R. B., Gast, J., Kraus, S., and Bogers, M. (2015). Coopetition: a systematic review, synthesis, and future research directions. *Review of managerial science*, 9:577–601.
- Brandenburger, A. M. and Nalebuff, B. J. (2011). *Co-opetition*. Currency.
- Brouwer, T. and Potters, J. (2019). Friends for (almost) a day: Studying breakaways in cycling races. *Journal of Economic Psychology*, 75:102092.
- Buchanan, J. M. and Tullock, G. (1965). *The calculus of consent: Logical foundations of constitutional democracy*, volume 100. University of Michigan press.
- Camerer, C. F., Nave, G., and Smith, A. (2019). Dynamic unstructured bargaining with private information: theory, experiment, and outcome prediction via machine learning. *Management Science*, 65(4):1867–1890.
- Charness, G. and Rabin, M. (2000). Social preferences: Some simple tests and a new model.
- Chen, D. L., Schonger, M., and Wickens, C. (2016). otree—an open-source platform for laboratory, online, and field experiments. *Journal of Behavioral and Experimental Finance*, 9:88–97.

- Chen, Y. and Eraslan, H. (2013). Informational loss in bundled bargaining. *Journal of Theoretical Politics*, 25(3):338–362.
- Chen, Y. and Eraslan, H. (2014). Rhetoric in legislative bargaining with asymmetric information. *Theoretical Economics*, 9(2):483–513.
- Chim-Miki, A. F. and Batista-Canino, R. M. (2017). Tourism coopetition: An introduction to the subject and a research agenda. *International Business Review*, 26(6):1208–1217.
- Cooper, D. J. and Kagel, J. H. (2016). Other-regarding preferences. *The handbook of experimental economics*, 2:217.
- Corchón, L. C. and Serena, M. (2016). Contest theory: A survey. *Handbook of Game Theory and Industrial Organization*.
- Croson, R., Boles, T., and Murnighan, J. K. (2003). Cheap talk in bargaining experiments: lying and threats in ultimatum games. *Journal of Economic Behavior & Organization*, 51(2):143–159.
- Croson, R. T. (1996). Information in ultimatum games: An experimental study. *Journal of Economic Behavior & Organization*, 30(2):197–212.
- Croxton, J. (2023). Eyewitness: Inside a tour de france team briefing with israel premier-tech. *Cycling News*, July 5, 2023.
- Dechenaux, E., Kovenock, D., and Sheremeta, R. M. (2015). A survey of experimental research on contests, all-pay auctions and tournaments. *Experimental Economics*, 18:609–669.
- Della Corte, V. and Aria, M. (2016). Coopetition and sustainable competitive advantage. the case of tourist destinations. *Tourism Management*, 54:524–540.
- Dilger, A. and Geyer, H. (2009). The dynamic of bicycle finals: A theoretical and empirical analysis of slipstreaming. *Economic Analysis and Policy*, 39(3):429–442.

BIBLIOGRAPHY

- Edgell, D. L. and Haenisch, R. T. (1995). *Coopetition: Global tourism beyond the millennium; charting the course for education, government, and commerce*. Internat. Policy Publ.
- Edgeworth, F. Y. (1881). *Mathematical psychics: An essay on the application of mathematics to the moral sciences*. Number 10. CK Paul.
- Eraslan, H. and Evdokimov, K. S. (2019). Legislative and multilateral bargaining. *Annual Review of Economics*, 11(1):443–472.
- Falk, A. and Fischbacher, U. (2006). A theory of reciprocity. *Games and economic behavior*, 54(2):293–315.
- Fehr, E. and Schmidt, K. M. (1999). A theory of fairness, competition, and cooperation. *The Quarterly Journal of Economics*, 114(3):817–868.
- Fréchette, G. R. (2012). Session-effects in the laboratory. *Experimental Economics*, 15:485–498.
- Fudenberg, D. and Tirole, J. (1983). Sequential bargaining with incomplete information. *The Review of Economic Studies*, 50(2):221–247.
- Gavrilets, S. (2015). Collective action problem in heterogeneous groups. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370(1683):20150016.
- Gernsheimer, O., Kanbach, D. K., and Gast, J. (2021). Coopetition research-a systematic literature review on recent accomplishments and trajectories. *Industrial Marketing Management*, 96:113–134.
- Gorman, J. C. (2014). Team coordination and dynamics: Two central issues. *Current Directions in Psychological Science*, 23(5):355–360.
- Gürtler, O., Struth, L., and Thon, M. (2023). Competition and risk-taking. *European Economic Review*, 160:104592.

- Güth, W., Huck, S., and Ockenfels, P. (1996). Two-level ultimatum bargaining with incomplete information: An experimental study. *The Economic Journal*, 106(436):593–604.
- Hardin, J. W. and Hilbe, J. M. (2002). *Generalized estimating equations*. chapman and hall/CRC.
- Harsanyi, J. C. and Selten, R. (1988). *A general theory of equilibrium selection in games*. MIT Press Books, 1.
- Hayes-Renshaw, F., Van Aken, W., and Wallace, H. (2006). When and why the EU council of ministers votes explicitly. *JCMS: Journal of Common Market Studies*, 44(1):161–194.
- Heinz, M. and Schumacher, H. (2017). Signaling cooperation. *European Economic Review*, 98:199–216.
- Human Rights Watch (2024). Germany throws a spanner in works of the eu supply chain law. <https://www.hrw.org/news/2024/01/29/germany-throws-spanner-works-eu-supply-chain-law>. Accessed: 2024-03-30.
- Kagel, J. H., Kim, C., and Moser, D. (1996). Fairness in ultimatum games with asymmetric information and asymmetric payoffs. *Games and Economic Behavior*, 13(1):100–110.
- Kahneman, D. (2008). Personal communication with Michael Bar-Eli. *Google Scholar*.
- Kavirathna, C. A., Kawasaki, T., and Hanaoka, S. (2019). Intra-port coopetition under different combinations of terminal ownership. *Transportation Research Part E: Logistics and Transportation Review*, 128:132–148.
- Kennan, J. and Wilson, R. (1993). Bargaining with private information. *Journal of Economic Literature*, 31(1):45–104.
- Krumer, A. and Lechner, M. (2017). First in first win: Evidence on schedule effects in round-robin tournaments in mega-events. *European Economic Review*, 100:412–427.

BIBLIOGRAPHY

- Lewicki, R. and Polin, B. (2013). Trust and negotiation. In *Handbook of research on negotiation*, pages 161–190. Edward Elgar Publishing.
- Ma, Z. (2023). Efficiency and surplus distribution in majoritarian reputational bargaining. *Journal of Economic Theory*, 210:105649.
- Malueg, D. A. and Yates, A. J. (2010). Testing contest theory: evidence from best-of-three tennis matches. *The Review of Economics and Statistics*, 92(3):689–692.
- Miettinen, T. and Vanberg, C. (2024). Commitment and conflict in unanimity bargaining. *American Economic Journal: Microeconomics*, forthcoming.
- Mignot, J.-F. (2016). *Strategic Behavior in Road Cycling Competitions*, chapter 10, pages 207–231. Springer International Publishing, Cham.
- Miller, L., Montero, M., and Vanberg, C. (2018). Legislative bargaining with heterogeneous disagreement values: Theory and experiments. *Games and Economic Behavior*, 107:60–92.
- Mintel, J. and Ondarza, N. v. (2022). More EU decisions by qualified majority voting-but how? legal and political options for extending qualified majority voting. SWP Comment 61, German Institute for International and Security Affairs, Berlin.
- Mitzkewitz, M. and Nagel, R. (1993). Experimental results on ultimatum games with incomplete information. *International Journal of Game Theory*, 22:171–198.
- Montero, M. (2007). Inequity aversion may increase inequity. *The Economic Journal*, 117(519):C192–C204.
- Münster, J. (2007). Simultaneous inter-and intra-group conflicts. *Economic Theory*, 32(2):333–352.
- Nash, J. F. (1950). The bargaining problem. *Econometrica*, 18(2):155–162.

- Neugart, M. and Richiardi, M. G. (2013). Sequential teamwork in competitive environments: Theory and evidence from swimming data. *European Economic Review*, 63:186–205.
- Palacios-Huerta, I. (2003). Professionals play minimax. *The Review of Economic Studies*, 70(2):395–415.
- Piazzolo, D. (2024). The “German Vote” and its consequences: (Un)reliable parties in multilateral bargaining under private information. unpublished.
- Piazzolo, D. and Vanberg, C. (2024a). Legislative bargaining with private information: A comparison of majority and unanimity rule. Working Paper 753, Heidelberg University, Heidelberg.
- Piazzolo, D. and Vanberg, C. (2024b). Multilateral bargaining with private information – experimental results on the comparison of different voting rules. unpublished.
- Rapoport, A. and Sundali, J. A. (1996). Ultimatums in two-person bargaining with one-sided uncertainty: Offer games. *International Journal of Game Theory*, 25:475–494.
- Roth, A. E. et al. (1995). Bargaining experiments. *Handbook of experimental economics*, 1:253–348.
- Rubinstein, A. (1982). Perfect equilibrium in a bargaining model. *Econometrica: Journal of the Econometric Society*, pages 97–109.
- Schmidt, D., Shupp, R., Walker, J. M., and Ostrom, E. (2003). Playing safe in coordination games: the roles of risk dominance, payoff dominance, and history of play. *Games and Economic Behavior*, 42(2):281–299.
- Schnedler, W. and Vanberg, C. (2014). Playing ‘hard to get’: An economic rationale for crowding out of intrinsically motivated behavior. *European Economic Review*, 68:106–115.

BIBLIOGRAPHY

- Schuette, L. (2019). Should the EU make foreign policy decisions by majority voting. *Center for European Reform*.
- Schweitzer, M. and Croson, R. (1999). Curtailing deception: The impact of direct questions on lies and omissions. *International Journal of Conflict Management*, 10(3):225–248.
- Selten, R. (1975). Reexamination of the perfectness concept for equilibrium points in extensive games. *International Journal of Game Theory*, 4:301–324.
- Straub, P. G. (1995). Risk dominance and coordination failures in static games. *The Quarterly Review of Economics and Finance*, 35(4):339–363.
- Szymanski, S. (2003). The economic design of sporting contests. *Journal of Economic Literature*, 41(4):1137–1187.
- Tsai, T.-S. (2009). The evaluation of majority rules in a legislative bargaining model. *Journal of Comparative Economics*, 37(4):674–684.
- Tsai, T.-S. and Yang, C. (2010a). Minimum winning versus oversized coalitions in public finance: The role of uncertainty. *Social Choice and Welfare*, 34(2):345–361.
- Tsai, T.-S. and Yang, C. (2010b). On majoritarian bargaining with incomplete information. *International Economic Review*, 51(4):959–979.
- Walker, M. and Wooders, J. (2001). Minimax play at wimbledon. *American Economic Review*, 91(5):1521–1538.
- Wang, Y. and Krakover, S. (2008). Destination marketing: competition, cooperation or coopetition? *International Journal of Contemporary Hospitality Management*, 20(2):126–141.