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Competing for Market Shares: Why the Order of Moves Matters Even When It Shouldn't

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Competing for Market Shares: Why the Order of Moves Matters Even When It Shouldn't

February 19, 2016

Abstract

This paper analyzes a contest for market shares where two homogeneous firms compete by investing either simultaneously or sequentially. Standard theory predicts that equilibrium investments and payoffs are independent of the order of moves. To test this prediction, we implement two treatments in the lab, one where firms chose investments simultaneously, and one where they invest sequentially. Our results suggest that it is an inherent advantage to move second rather than first even in the absence of strategic concerns, since first movers face strategic uncertainty, while second movers have the power to ultimately determine relative payoffs through their investment choices. This power is particularly valuable in our experiments, since many first movers try to establish a collusive outcome and second movers not only care about own monetary earnings, but also about relative standing vis-à-vis the first mover.

JEL-Classification: C72, C92, D21, D74, L13, L22, M37

Keywords: Sequential Competition; Order of Moves; Experiment; Relative Income Hypothesis; Collusion; Market-Share-Attraction Model

1 Introduction

Most real world markets are characterized by oligopolistic competition meaning that only a few firms compete for a large number of potential buyers. For instance, there are less than a dozen independent automobile producers worldwide, three leading food processing companies together achieve a large share of global processed food sales, there are only a handful of different brands of household detergents, etc. Core characteristic of oligopolistic markets are that prices, quantities and marketing expenditures are chosen strategically, and that the ability to pre-commit has strategic value. The question how the ability to pre-commit to a choice affects market outcomes has attracted the attention of theorists for a long time ever since the pioneering contribution by von Stackelberg (1934). Empirical work on the effects of commitment is still scarce, even though some of the main theoretical predictions were recently tested in lab experiments (by Huck et al. 2001 and by Kübler and Müller 2002, for instance).

This paper investigates in lab experiments whether the ability to pre-commit matters even in the absence of strategic considerations. In particular, we consider a contest for market shares where two homogeneous firms compete by either simultaneously or sequentially making investment decisions. A particular feature of this model (first mentioned by Dixit 1987) is that equilibrium investments and payoffs are independent of the order of moves. This implies that in the theoretical benchmark there is neither a value of commitment for the leader, nor a value of information for the follower, nor a first- or a second-mover advantage.[1] To test whether the order of moves affects behavior even in the absence of strategic considerations, our experiments feature two treatments implemented in a between-subjects design: Subjects choose the amounts they want to invest simultaneously in treatment SIM, while investments are made sequentially in treatment SEQ. Independent of the treatment, subjects face a one-shot interaction in part 1 and a finitely repeated interaction in part 2 of the experiment.

Even though theory predicts neither a first-mover nor a second-mover advantage, our results suggest that it is an inherent advantage to move second rather than first, both in the one-shot and in the repeated interaction. While the benchmark model – based on the assumption of own-money maximizing players – is unable to explain observed behavior even if we allow for off-equilibrium choices by first movers, we find that an alternative model based on the "relative income hypothesis" pioneered by Duesenberry (1949) does quite well

[1] Here and throughout the term "value of commitment for the first mover" ("value of information for the second mover") stands for the additional equilibrium payoff the first mover (the second mover) receives in the sequential-move version of the game as compared to payoff of the same player in the simultaneous-move version. By contrast, the terms "first-mover advantage" and "second-mover advantage" refer to the comparison of equilibrium payoffs across the two players within the sequential-move version of the game.

in organizing the data. In a nutshell, the alternative model – applied to our experimental data – suggests that the inherent advantage to move second rather than first even in the absence of strategic concerns arises because second movers have the power to ultimately determine the relative payoffs while first movers face strategic uncertainty regarding second mover investments.

Our results have important implications for different subfields of economics and business. First and foremost, this paper contributes to the literature on strategic firm behavior in duopolies. In particular, our work is closely related to Huck, Müller, and Normann (2001) and Kübler and Müller (2002) who investigate how the order of moves affects firm behavior when the quantities supplied and the prices charged from consumers, respectively, are the strategic choice variables of firms. The major conceptual difference to these papers is that variations in the order of moves have no strategic effect in the standard benchmark of the setting we consider, while theory predicts a positive value of commitment, a negative value of information and a first-mover advantage in the quantity-competition setting and a positive value of commitment, a positive value of information and a second-mover advantage in the price-competition environment.

Second, we contribute to the literature on strategic marketing investments, since the setting we consider can be interpreted as a "market-share-attraction" model with combative advertising where the size of the market is fixed (Friedman 1958). We are not aware of any study that uses experimental methods to investigate how the order of moves affects advertising investments in this particular version of the market-share-attraction model.[2] Our findings are in line with empirically observed advertising wars in slow growth industries where market share gains are the driving force behind expansions. More specifically, our findings suggest that concerns for relative standing within an industry might explain why "advertising wars that often produce mutually damaging consequences and that advertisers who engage in them often regret" (Beard 2011, p.399) are frequently observed – think of the so-called 'Cola' or 'Burger' wars, for example.[3]

Third, this paper is related to the literature on contests with sequential moves. Contestants compete for shares of the prize at stake in our study, however, and not for winning or losing the entire prize as other papers in that literature typically assume. While Shogren and Baik (1992) as well as Weimann, Yang, and Vogt (2000) differ from our study in several dimensions – in particular by considering environments where theory predicts a first-mover

[2]See Bass, Krishnamoorthy, Prasad, and Sethi (2005) or Chen, Joshi, Raju, and Zhang (2009) and the references therein for more complex models that do not take prices as given, that allow for different types of marketing activity, and that accounted for dynamic aspects of the competition.

[3]See also Beard (2010) for details and further examples.

advantage – Fonseca (2009) is more closely related. He considers symmetric treatments with a probabilistic payoff function in which the order of moves leaves equilibrium choices and (expected) payoffs unaffected.[4] The probabilistic payoff function implies, however, that SMs cannot ultimately determine relative payoffs through their own investment choice, but only the probability with which the SM is either better-off (if she wins) or worse-off (if the FM wins) than the opponent. It is thus consistent with our explanation of the observed second-mover advantage – according to which the power of SMs to ultimately determine relative payoffs through own investment choices is crucial – that Fonseca (2009) observes neither a first- nor second-mover advantage. In this sense, we also contribute to the recent literature that reports behavioral differences across share and probability contests.[5]

In terms of practical implications, it is worth noting that firms are run by CEOs and their managers, and not by experimental subjects. It seems natural to assume, however, that CEOs and senior managers care – if anything – even more about their relative standing than subjects in our experiments do. In particular, the relative performance evaluation hypothesis – a corollary of the informativeness principle by Holmström (1982) – predicts that CEO pay should at least partly reflect the relative performance of the firm compared to some industry average to filter out common shocks. Consequently, firm leaders might sometimes even have monetary incentives to care about relative incentives. We observe, however, that decision makers in the experiment care about relative standing even in the absence of such monetary incentives. In this sense, we contribute to the literature that tries to explain the relative performance evaluation puzzle – the documented lack of a positive relationship between CEO compensation and relative performance that the relative performance evaluation hypothesis predicts.[6] Our findings complement Aggarwal and Samwick (1999a) by showing that concerns for relative standing intensify competition in oligopolies, reduce profits, and are thus suboptimal from the perspective of shareholders even in the absence of contracts that generate monetary incentives for relative standing. What we observe in thus in line with the behavioral explanation of the relative performance evaluation puzzle by Fershtman, Hvide, and Weiss (2003) who assume in their model that it is a human tendency to compare outcomes with other individuals, such that CEOs derive additional (non-monetary) utility from outperforming competitors.

The remainder of this paper is structured as follows. Section 2 introduces the formal model

[4]Fonseca (2009) also implements treatments with heterogeneous contestants in which theory predicts a positive value of commitment and a first-mover advantage. These treatments are less relevant for our study, however.

[5]See Chowdhury, Sheremeta, and Turocy (2014) or Eisenkopf and Teyssier (2014), for example, and the references cited therein.

[6]See Aggarwal and Samwick (1999b) as well as the survey articles by Prendergast (1999) and Murphy (1999) for further details.

and derives the theoretical benchmark – based on the assumption of own-money maximizing players – for the simultaneous move and the sequential move game. The experimental design is introduced in Section 3. Section 4 presents our main findings. Potential explanations of observed behavior are presented in Section 5 and then discussed in Section 6. Section 7 concludes.

2 Theoretical Analysis

The Model. Consider contest where two symmetric firms compete for market shares rather than for winning the entire market. For the sake of an example that facilitates the subsequent exposition, assume that advertising is the strategic choice variable of firms such that firms compete for market shares through advertising investments. Advertising investments x_i by any firm $i \in \{1, 2\}$ increase the share of the market that firm i serves, while investments by the opponent reduce i's market share. The size of the market is assumed to be independent of advertising investments and fixed at M, which implies that advertising has no effect on the absolute demand for the considered product category.

Following Friedman (1958), the share of the market that i serves is assumed to be determined by the share of advertising by firm i in total advertising by all firms.[7] The market share of firm i is thus given by

$$s_i(x_i, x_{-i}) = \begin{cases} \frac{x_i}{x_i + x_{-i}} & \text{if} \quad x_i + x_{-i} > 0 \\ 0.5 & \text{if} \quad x_i + x_{-i} = 0, \end{cases}$$

where x_i is the investment chosen by firm i and x_{-i} is the investment of the competitor. Assuming linear investment costs and own profit as the only motive, the optimization problem of firm i reads

$$\max_{x_i \geq 0} \Pi_i(x_i, x_{-i}) = \frac{x_i}{x_i + x_{-i}} M - x_i \ . \tag{1}$$

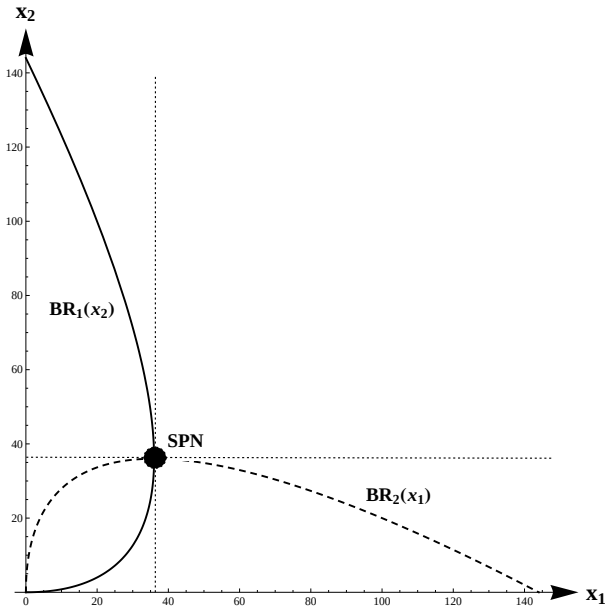
First-order optimality conditions deliver the best-response function of firm i for given investments x_{-i} by the competitor

$$\mathrm{BR}_i(x_{-i}) = \max\{\sqrt{x_{-i} M} - x_{-i}, 0\} \ .$$

Figure 1 plots the standard best-response functions of the two firms for $M = 1$ and reveals that these functions have an inverted U-shape. This is different in typical industrial organi-

[7] This specification is identical to the well known Tullock (1980) contest technology with a share (rather than a probability) interpretation.

Figure 1: Best-Response Functions and the SPNE



Note: The figure plots the best-response function of the two firms for the parameters used in the experiments ($M = 144$).

zation models with price or quantity competition, where best-response functions are either monotonically increasing in the relevant range (in price competition models) or monotonically decreasing in the relevant range (with quantity competition). As will become clear below, the property that best responses of symmetric firms cross at the 'top of the hill' (where the slope is zero) implies that there is neither a positive or negative value of commitment for the FM, nor a positive or negative value of information for the SM, nor a first- or second-mover advantage in the theoretical benchmark of our model.

Simultaneous Investment Decisions. For the setting where the two firms make their investment decisions simultaneously (denoted `SIM`) the equilibrium occurs at the point where best response functions cross. The crossing conditions $x_1^* = BR_1(x_2^*)$ and $x_2^* = BR_2(x_1^*)$ deliver equilibrium investments

$$x_{\texttt{SIM}}^* \equiv x_1^* = x_2^* = \frac{M}{4} \ . \tag{2}$$

These investments imply equilibrium profits for the simultaneous move game of:

$$\Pi_{\texttt{SIM}}^* \equiv \Pi_1(x_1^*, x_2^*) = \Pi_2(x_2^*, x_1^*) = \frac{M}{4} \ . \tag{3}$$

Sequential Investment Decisions. Consider next the setting (denoted `SEQ`) where firm 1 (the FM, he) commits to an investment level first which is then perfectly observed by firm 2 (the SM, she) before she makes her own investment choice. In a subgame-perfect equilibrium of `SEQ` the FM perfectly anticipates how the SM reacts to each investment choice and – given the anticipated reaction – he searches for the own best reply. Technically the best-response function of the SM is plugged into the optimization problem of the FM. Maximization then yields the equilibrium investment of the FM. To determine equilibrium investment of the SM, we then insert the equilibrium investment of the FM into the SM's best-response function. In our model where firms are homogeneous, they choose the same level of investments in equilibrium:

$$x^*_{\texttt{SEQ-FM}} \equiv x^*_1 = x^*_{\texttt{SEQ-SM}} \equiv x^*_2 = \frac{M}{4} \ . \tag{4}$$

The resulting equilibrium profits for both contestants read

$$\Pi^*_{\texttt{SEQ-FM}} \equiv \Pi_1(x^*_1, x^*_2) = \Pi^*_{\texttt{SEQ-SM}} \equiv \Pi_2(x^*_2, x^*_1) = \frac{M}{4}. \tag{5}$$

Discussion. The comparison of the theoretical benchmarks for investments and payoffs across `SIM` and `SEQ` shows that equilibrium investments and payoffs are the same across settings (`SIM` vs. `SEQ`) and within a setting the same across players – a point previously made by Dixit (1987). This implies that in the benchmark there is neither a positive or negative value of commitment, nor a positive or negative value of information, nor a first-mover or second-mover advantage. The reason is that investment decisions are locally neutral, i.e. they are locally neither strategic complements nor strategic substitutes.[8] This is illustrated in Figure 1: The slope of the best reply is strictly positive to the left of the unique point of intersection and strictly negative to the right of that point – but it is exactly zero at the point of intersection. This is different in standard industrial organization models where best-response functions are typically either monotonically increasing or monotonically decreasing in the relevant range.[9] At the same time, the setting we consider is similar to standard IO models in other dimensions that are important when comparing simultaneous and sequential move games. In particular, the strategic choice of each firm affects both the own profit and the profit of the opponent independently of whether the choice of the opponent is held constant or is adjusted according to the standard best reply – just as in quantity or price competition models. That is, although investments are locally neutral from a strategic point of view,

[8] The actions of two players are strategic substitutes (strategic complements) if the best response function is downward sloping (upward sloping) – assuming that the objective functions are strictly concave. See Bulow, Geanakoplos, and Klemperer (1985)

[9] See Gal-Or (1985), for example, who shows that downward sloping (upward sloping) best response functions typically lead to a first-mover (second-mover) advantage.

they still produce externalities as in typical industrial organization models.[10] Moreover, the competition for market shares also allows for collusive outcomes just as in standard price and quantity competition models. Independent of the order of moves, profits of both firms are twice as high as in the competitive solution if both firms invest nothing, since investments have only distributional effects.

3 Design of the Experiments

Experimental Parameters and Treatments. We implement the two timing protocols `SIM` and `SEQ` in a between subject design meaning that experimental subjects either decide simultaneously about their investments (in treatment `SIM`), or sequentially (in treatment `SEQ`). Everything else is held constant across treatments. In particular, the market value is set to $M = 144$ in both treatments. We ran 2 sessions for treatment `SIM` and 4 sessions for treatment `SEQ` with 20 participants each. All 120 subjects were students from the University of Innsbruck and each subject participated only once. The experiment was programmed in z-tree (Fischbacher 2007) and students were recruited using ORSEE (Greiner 2004). The experimental currency unit 'Taler' was converted to Euro at an exchange rate of 50:1 at the end of the experiment. Each session lasted about 70 minutes, and subjects earned slightly more than 15 Euro on average (including a show up fee of 4 Euros).[11]

Implementation. At the beginning of each session, participants received general instructions and were informed that the experiment has four parts. They were also informed that their earnings in each part will depend on the own decisions and on the decisions of at most one anonymous second participant. We are only interested in parts 1 and 2 subsequently, which implement a one-shot version of the market interaction (part 1) and a finitely repeated market with partner matching (part 2), respectively. After reading the instructions for part 1, subjects had the possibility to test and improve their understanding of the instructions in a training programm.[12] In this training program, subjects could fill in different values of the decision variable both for themselves and for a hypothetical partner. After confirming their choices, they were informed about the resulting division of the market and the payoffs. The training period lasted about 6 minutes as subject made intensive use of the program by

[10] In the advertising competition application we consider the externality of the action choice is negative, just as in standard quantity competition models (where choice variables are strategic substitutes) – and in contrast to price competition models where the externality is typically positive.

[11] The average payoff does also include earnings in two additional experimental parts that were conducted after our main experiment and unrelated to our study.

[12] A translated version of general instructions and of instructions for part 1 is provided in the appendix. The original (German) instructions are available from the authors upon request.

Table 1: Standard Predictions and Parameters

	SIM	SEQ-FM	SEQ-SM
Payoff (Π_i)	36	36	36
Investment (x_i)	36	36	36
Market Size (M)	144	144	144

entering many different investment combinations. After the training period, we started part 1 of the experiment where each subject was randomly matched with a partner. All subjects in SIM and FMs in SEQ were asked to provide an own investment and an estimate of the expected investment of the opponent. Decisions of SMs were elicited using real play rather than the strategy method, i.e., SMs were informed about the actual investment of the paired FM and responded only to this particular choice. After all decisions were made, subjects were informed about their own investment choice, the amount invested by the opponent, and both their own and the opponent's payoff. Subsequently, we started part 2 of the experiment. Instructions for part 2 were provided on the computer screen, as subjects were facing the same decision environment as in part 1. The only differences in part 2 was that partners were fixed for 12 decision rounds and that this was common knowledge. Subjects received the same feedback after each decision round as at the end of part 1 and were informed ex-ante that for part 2 only one randomly chosen decision round will be paid out at the end of the experiment. After subjects completed all parts of the experiment, they were asked to fill out a questionnaire (voluntary and not-incentivized).

Decision Environment. The decision environment in the experiment was neutrally framed in that we did not relate the strategic interaction to a particular application. Subjects had to decide how much of their endowment they want to invest in order to get a share of the prize. The endowment in part 1 and in each period of part 2 was 144 Taler and endowments could not be transferred across parts or periods. The prize was equal to the endowment (that is 144 Taler) in part 1 and in each period of part 2. In the SIM treatment subjects were not informed about the decision of the paired opponent before making their own choice. In the SEQ treatment each subject was first assigned a role – either the role of a FM or the role of a SM. These roles remained constant across parts and across periods in part 2. Whereas the FM received no information about the decision of the paired SM, the SM was informed about the paired FM's investment decision before making her own choice.

Hypothesis. Benchmark predictions for investment choices as well as for the resulting payoffs in treatments SIM and SEQ are provided in Table 1. Assuming play according to the standard benchmark, subjects should invest the same amount across treatments and roles. As a consequence, earnings of subjects in SIM and of FMs and SMs in SEQ should also be equal. This is summarized in our main hypotheses:

Hypothesis. *The order of moves does not affect equilibrium payoffs. Subjects in SIM as well as FMs and SMs in SEQ earn the same amount.*

$$\begin{array}{lrcl} \text{(a)} & \Pi_{\texttt{SIM}} & = & \Pi_{\texttt{SEQ-FM}} \\ \text{(b)} & \Pi_{\texttt{SIM}} & = & \Pi_{\texttt{SEQ-SM}} \\ \text{(c)} & \Pi_{\texttt{SEQ-FM}} & = & \Pi_{\texttt{SEQ-SM}} \end{array}$$

4 Experimental Results

4.1 Behavior and Outcomes in the One-Shot Interaction

Table 2 provides average payoffs and average investment choices in part 1 of the experiment – where subjects interact only once – by treatment and separately for FMs and SMs in SEQ. The standard benchmark of 36 is equal across all these measures and treatments. Before testing our hypothesis that focuses on the comparison of payoffs across treatments and roles, we investigate whether the averages for payoffs and investments are in line with the theoretically predicted values.[13] Average payoffs and investment choices in SIM are close enough to the benchmark predictions such that we cannot reject equality at conventional levels. The pattern is somewhat different in SEQ, both for FMs and SMs: FMs invest and earn significantly less than predicted – the respective p-values are 0.090 (for 29.00 vs. 36.00) and 0.000 (for 11.23 vs. 36.00), respectively. SMs invest significantly more than predicted (59.25 vs. 36.00; WSR: p=0.042) and their payoff is almost 25% higher than predicted. Somewhat surprisingly, the difference between the actual SM payoff and the predicted SM payoff is not significant at conventional levels, however (44.52 vs. 36.00; WSR: p=0.550). This is probably due to the large heterogeneity in payoffs that we discuss in more detail below.

Main Hypothesis. Consider next the comparisons of payoffs across treatments and roles as formulated in our main hypothesis. We use a nonparametric Mann-Whitney U-test (MWU) for across treatment comparisons that are necessary to evaluate parts (a) and (b) of our main hypothesis, and – given that decisions by FMs and SMs are not independent from each other –

[13] We use a Wilcoxon signed-rank test (WSR) to assess whether we can reject the null hypothesis that $x_i = 36$ and $\Pi_i = 36$, respectively. We only report p-values subsequently.

Table 2: Mean Payoffs and Investment Choices (One-Shot)

	SIM	SEQ-FM	SEQ-SM
Payoff (Π_i)	38.40	11.23	44.52
	(34.09)	(30.63)	(57.65)
Investment (x_i)	33.60	29.00	59.25
	(32.19)	(38.24)	(50.63)
Observations	40	40	40

Note: The table provides payoffs and investment choices in part 1 (one-shot) across 40 subjects in the respective treatment. Standard deviations are provided in parentheses.

a Wilcoxon signed-rank (WSR) test to evaluate part (c) of this hypothesis where decisions by FMs and SMs are compared. When comparing the average payoff of subjects in SIM and FMs in SEQ, we observe a negative value of commitment for FMs – in contrast to the theoretical benchmark prediction. In particular, FMs in SEQ earn (on average) significantly less than subjects in SIM (11.23 vs. 38.40; MWU: p=0.000), such that part (a) of our hypothesis can be rejected. At the same time, SMs appear to earn more than subjects in treatment SIM or FMs in SEQ – see Table 2. We cannot reject part (b) of the hypothesis (44.52 vs. 38.40, MWU: p=0.920), however, but find a significant difference in payoffs between the FM and the SM (44.52 vs. 11.23; WSR: p=0.005) – which allows us to reject part (c) of our hypothesis.

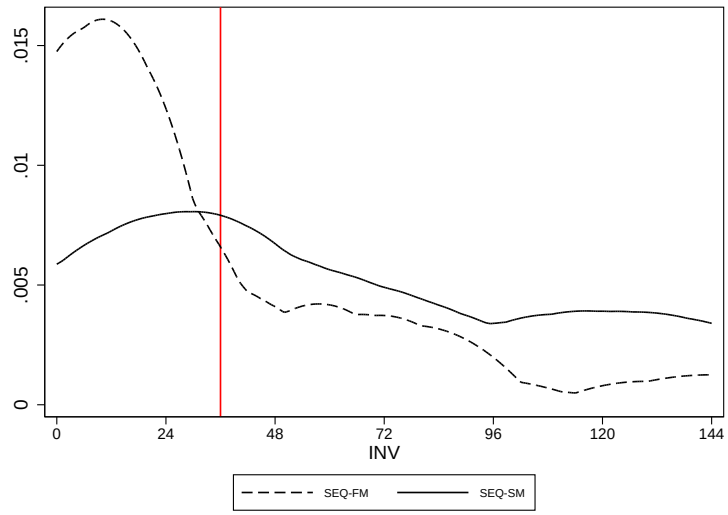
When taking a closer look at investment behavior, we find that average investments by subjects in SIM are not significantly different from investments by FMs in SEQ. However, from the results above we already know that FMs earn significantly less. Thus, behavior of SMs in SEQ is likely to be responsible for the decrease in FM payoffs: SMs invest significantly more than subjects in SIM (59.25 vs. 33.60; MWU: p=0.026) or FMs in SEQ (59.25 vs. 29.00; WSR: p=0.000).

Summing up, the experimental data show that sequential investment decisions deliver an asymmetry between FMs and SMs. In particular, moving first seems to hurt the FM in the experiment, both in comparison to the earnings in SIM and in comparison to the earnings of the SM in SEQ. The fact that FMs in SEQ invest similar amounts as subjects in SIM indicates that the choices by SMs in SEQ are responsible for this pattern.

Result 1 (**OS: Mean Outcomes**). *The data display a negative value of commitment for the FM. Moreover, we find some evidence for a positive value of information for the SM. Taken together, these findings deliver a second-mover advantage.*

Figure 2 presents a density plot of investment choices by FMs and SMs in SEQ. The plot

Figure 2: Density Function of FM- and SM-Investments (One-Shot)



Note: The figure approximates the distribution of investment in treatment SEQ, using an Epanechnikov kernel estimator with the optimal bandwidth.

clearly shows that investment choices of FMs are not concentrated around the equilibrium prediction of 36. Instead, it appears that the majority of FMs invests much less than predicted, even though some subjects also invest way more. Consequently, average investment choices of FMs fail to reveal behavior of the 'average subject'. Choices by SMs in SEQ are less concentrated and instead dispersed over the entire strategy space. Given that SMs invest conditional on observed FM investment, SM choices are hard to interpret in isolation. Nevertheless, the density plot shows that – in comparison to FMs – there are far less SMs who invest less than predicted, and way more who invest high amounts. Moreover, the distribution indicates that the high value of the mean investment by SMs in SEQ is to a large extent due to the fraction of SMs who invests very high amounts, rather than due to high investments of a representative SM. Consequently, average investment choices and payoffs in Table 2 hide a substantial amount of heterogeneity across FMs and SMs in the experimental data. To better account for the substantial heterogeneity in investment choices by FMs in SEQ, and to investigate whether this heterogeneity in behavior may help to explain the asymmetry across FMs and SMs that we observe, we subsequently disaggregate the data in two subgroups. In particular, we separately analyze payoffs and expectations of FMs who invest less than the predicted amount of 36, and of FMs who choose the predicted amount of investment or more. This classification has several advantages: First, it accounts for the bimodal distribution of FM investment choices and thus facilitates the interpretation of SM responses. Second, it delivers an almost natural classification of moves. In particular, below equilibrium investments by FMs might be interpreted as an invitation to 'collude', whereas

Table 3: Payoffs by FM-Investment (One-Shot)

	(1) $x_{\texttt{SEQ-FM}} < 36$	(2) $x_{\texttt{SEQ-FM}} \geq 36$
$\Pi_{\texttt{SEQ-FM}}$	18.21	-5.07
$\Pi_{\texttt{SEQ-SM}}$	68.07	-10.43
Obs.	28	12

Note: The table presents average earnings in experimental currency units net of the endowment that subjects receive.

above equilibrium investments are an indication of intense competition.[14] Finally, this classification accounts for the sensitivity of the reaction function slope to the FM choice, since investments are strategic complements below and strategic substitutes above the predicted amount of 36, respectively.

Table 3 presents mean payoffs of FMs and SMs net of the endowment. Consider first the subgroup of FMs who invest less than the predicted amount in column (1). Note that this group accounts for roughly 70% of all observations. The payoff that these FMs receive is significantly lower than the amount SMs receive on average (18.21 vs. 68.07; WSR: p=0.001). This is different for FMs who invest more than predicted – see column (2) of Table 3. We find no significant difference between the payoffs of FMs who belong to this subgroup and those of their opponents. If anything, the numbers suggest that these FMs are even slightly better (or less worse) off than the opponents (-5.07 vs. -10.43).

Taken together, we find that FMs who choose an investment below the benchmark prediction earn much less than their paired SMs, while FMs who choose an investment above the benchmark prediction appear to earn the same amount as the paired SMs. When comparing realized FM-payoffs across these two subgroups, however, we find that FMs who invest low amounts earn significantly more in absolute terms than those who invest high amounts (18.21 vs. -5.07; MWU: p=0.019).[15] This suggests that FMs might want invest low rather than high amounts to maximize their payoff, even though this implies that they earn less than their competitor.

Result 2 (**OS: Disaggregated Data in SEQ**). *The disaggregated data in SEQ show that*

(a) the majority of FMs invests less than the standard benchmark predicts, while roughly

[14] Given that the number of choices 'around' the predicted value of 36 is rather low – there are only three FMs who choose an investment level between 30 and 42, for example – we decided against a classification in three subgroups.

[15] See also Figure 8 in the appendix which plots FM payoff as a function of FM investment.

Table 4: Mean Payoffs and Investment Choices (Repeated)

	SIM	SEQ-FM	SEQ-SM
Payoff (Π_i)	28.22	27.14	39.77
	(25.19)	(20.97)	(30.40)
Investment (x_i)	43.78	36.64	40.45
	(25.19)	(26.21)	(23.46)
Observations	40	40	40

Note: The table provides average payoffs and investment choices in part 2 (repeated interactions) across 40 subjects in the respective treatment. Standard deviations are provided in parentheses and are computed using between and ignoring within subject variation in repeated interactions.

30% invest more.

(b) FMs who invest less than the benchmark prediction earn less than paired SMs.

(c) FMs who invest more than the benchmark prediction earn the same as paired SMs.

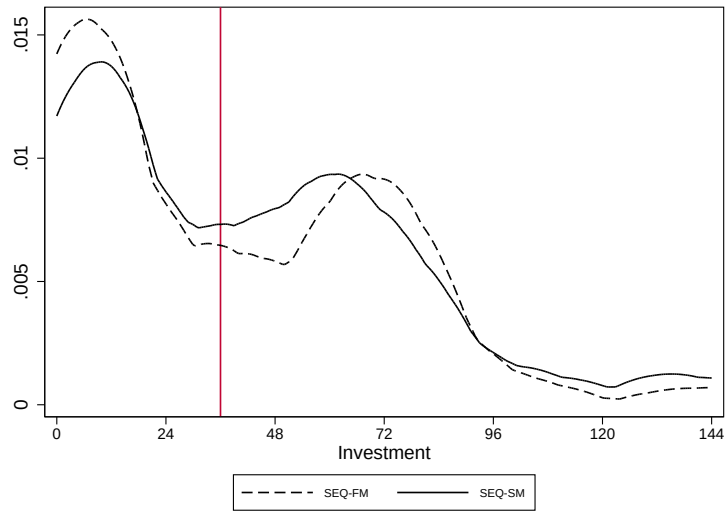
(d) FMs who invest low amounts earn significantly more than FMs who invest high amounts.

4.2 Behavior and Outcomes across Repeated Interactions

Table 4 provides average payoffs and investment choices across 12 repeated interactions with partner matching in part 2 of the experiment for treatments SIM and SEQ. Given that we consider a game with a finite number of repetitions, predictions from the one-shot carry over to repeated interactions – implying that the benchmark prediction of 36 is equal across all measures and treatments. Interestingly, we find that the only measure that is significantly different from benchmark predictions are average earnings by FMs – they earn significantly less (27.14 vs. 36.00; WSR: p=0.008). Pairwise comparisons of investment choices across treatments indicate that SM-investment exceeds FM-investment in SEQ (40.45 vs. 36.34; WSR: p=0.082), while we cannot reject the null that subjects in SIM invest the same amount as either FMs or SMs in SEQ. In this sense, investment choices are more similar across SIM and SEQ in repeated interactions than in the one-shot interaction, and the only prevailing difference is across FMs and SMs in SEQ.

Main Hypothesis. Regarding payoffs and our main hypothesis, results are qualitatively similar to those in the one-shot with one notable exception: The difference in payoffs between

Figure 3: Density Function of FM- and SM-Investments (Repeated)



Note: The figure approximates the distribution of investment across 12 decision rounds with partner matching in treatment `SEQ`, using an Epanechnikov kernel estimator with the optimal bandwidth.

FMs in `SEQ` and subjects in `SIM` is economically small (28.22 vs. 27.14) and statistically insignificant (MWU: p-value 0.855) across repeated interaction, while the respective difference was large and highly significant in the one-shot.[16] Thus, the value of commitment for the FM is no longer negative but instead close to zero. On the other hand, the positive value of information for the SM is even more pronounced across repeated interaction, which implies that the second-mover advantage observed in the one-shot survives in repeated interaction. Specifically, SMs earn significantly more than FMs in `SEQ` (WSR: p-value 0.002) and earn more than subjects in `SIM` – even though the latter difference is beyond the border of being significant in statistical terms (MWU: p-value 0.121).[17]

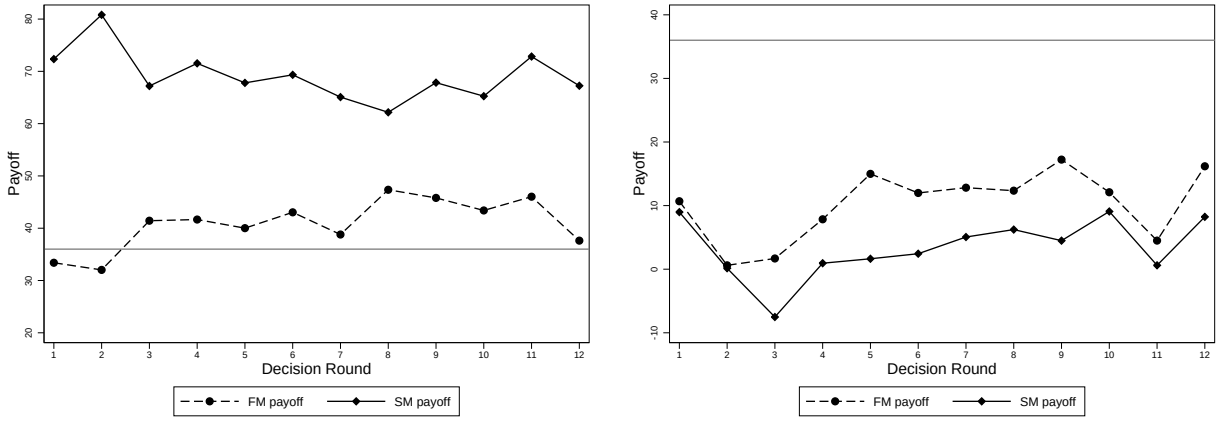
Result 3 (**REP: Mean Outcomes**). *We observe a value of commitment for the FM that is close to zero across repeated interactions. Moreover, the data display a positive value of information for the SM. Taken together, these findings deliver a second-mover advantage.*

Figure 3 presents a density plot of investment choices by FMs and SMs in `SEQ` across all decision rounds. As in the one-shot, investment choices of FMs are not concentrated around the benchmark prediction of 36. Instead, the distribution of FM investments is clearly bimodal: One mode is close to 12 and thus way below the benchmark prediction, while the second mode is close to 72 and thus above the benchmark prediction. The distribution of SM investments is similar, but low investments are slightly less often observed, while investments

[16]Before applying the MWU or WSR test we take average investment levels across all rounds for each individual, which implies that the number of observations is 40 for each treatment.

[17]For robustness checks we use also a regression analysis to identify treatment effects and find that results are qualitatively the same. The regression results are available upon request.

Figure 4: FM- and SM-payoffs by Decision Round (Repeated)



(a) $x_{\texttt{SEQ-FM}} < 36$ (b) $x_{\texttt{SEQ-FM}} \geq 36$

Note: The figures displays average payoffs of FMs and SMs by decision round in treatment `SEQ` conditional on FM investment.

that exceed the benchmark prediction are more frequent – which was to be expected, given that the average SM investment is significantly higher than the average FM investment. The density plot illustrates that mean investments do not reflect average behavior by experimental subjects. Rather, it seems that FMs invest either high or low amounts in the majority of cases, while investment choices close to the theoretical benchmark are chosen less frequently.

To account for the bi-modality of FM investments, we subsequently disaggregate the data and separately consider FMs who invest *less* than the benchmark predictions, and FMs who invest *more* than the benchmark prediction. As in the one-shot, we again compare payoffs of FMs and SMs. Figure 4 provides the respective measures for both subgroups by decision round. Consider panel (a) first. Here FMs invest less than the benchmark prediction and just as in the one-shot, we find that average SM earnings exceed FM earnings in every decision round. FMs who invest *more* than the benchmark prediction, however, earn (slightly) more than the paired SM – see panel (b) of Figure 4.

While these relations are immediately apparent from the figure, statistical inference is less straightforward – given that the same individual may invest more than the benchmark prediction in some decision rounds and less in others.[18] Abstracting from experience-driven changes in behavior across decision rounds, we compute FM averages across all rounds in which the FM invests less (more) than the benchmark prediction – implying that between 1 and 12 decision-round observations determine averages on the individual level. Table 5 provides the realized payoffs of FMs and SMs across FMs who invest less than the benchmark

[18]In fact, we find that 13 (7) individuals invest less (more) than the benchmark prediction in all decision rounds. The remaining 20 individuals have investments above and below the standard benchmark.

Table 5: Realized and Expected Payoffs by FM-Investment (Repeated)

	(1) $x_{\texttt{SEQ-FM}} < 36$	(2) $x_{\texttt{SEQ-FM}} \geq 36$
$\Pi_{\texttt{SEQ-FM}}$	34.66	6.78
$\Pi_{\texttt{SEQ-SM}}$	67.09	1.70
Obs.	33	27

Note: The table presents average earnings in experimental currency units net of the endowment that subjects receive.

prediction in column (1), and across FMs who invest more than the benchmark prediction in column (2), respectively. WSR-tests indicate that the previously discussed differences that are displayed in Figure 4 are statistically significant:[19] FMs who invest *less* than the benchmark prediction earn less than paired SMs (34.66 vs. 67.09; p-value=0.001), while FMs who invest *more* than the benchmark prediction earn more than the paired SM (6.78 vs. 1.70; p-value=0.015).

When comparing realized FM-earnings across the two subgroups of FM, averages across columns (1) and (2) suggest that FMs earn more if they invest less than the benchmark prediction – just as in the one-shot. Non-parametric tests are not applicable here, however, since the mean difference across subgroups is partly determined by 'within-individual' and partly by 'across-individual' differences. We thus use random-effect panel regressions to account for both 'within-individual' and 'across-individual' differences, as well as fixed-effect panel regressions that only exploit 'within-individual' differences. In both cases, we control for decision-round fixed-effects and use robust standard errors for inference. Table 6 provides the estimation results. Consider first columns (1) and (2) which investigate whether average FM earnings increase or decrease if FMs invest less than the benchmark prediction, as compared to the case where FMs invest more than the benchmark prediction. Point estimates of the treatment effect are similar across random- and fixed-effect estimates and highly significant in both cases.[20] In particular, we find that FMs who invest less than the benchmark prediction earn significantly more than FMs who invest more. And as in the one-shot interaction, according to columns (3) and (4), FMs who invest less than the benchmark prediction are much worse-off in relative terms. In particular, the difference between realized FM- and SM-

[19] Using panel-regression techniques for inference that take account of changes across decision rounds leaves all major findings unaffected. Details available from the authors upon request.

[20] The similarity across random- and fixed-effect estimates indicate that SMs who are paired with FMs that switch subgroups behave similar as SMs who are paired with FMs that do not switch.

Table 6: Absolute and Relative FM-payoff (Repeated)

	$\Pi_{\texttt{SEQ-FM}}$		$\Pi_{\texttt{SEQ-FM}} - \Pi_{\texttt{SEQ-SM}}$	
	(1)	(2)	(3)	(4)
$\texttt{I}(x_{\texttt{SEQ-FM}} < 36)$	25.958	23.436	-38.757	-41.147
	(0.001)	(0.002)	(0.001)	(0.001)
	[14.67; 37.24]	[8.898; 37.884]	[-48.938; -28.576]	[-54.266; -28.029]
Round FE	YES	YES	YES	YES
Random Effects	YES	NO	YES	NO
Fixed Effects	NO	YES	NO	YES
Individuals	40	40	40	40
Decision Rounds	12	12	12	12
Obs.	480	480	480	480

Note: Robust standard errors – clustered on the pair level – are provided in parentheses; in brackets: 95% confidence interval of coefficient estimate. $\texttt{I}(x_{\texttt{SEQ-FM}} < 36)$ is a dummy variable that equals 1 if $x_{\texttt{SEQ-FM}} < 36$, and 0 if $x_{\texttt{SEQ-FM}} \geq 36$.

payoffs is roughly 40 units for FMs who invest low amounts. Just as for absolute earnings, random- and fixed-effect estimations deliver almost identical treatment effects.

Result 4 (REP: Disaggregated Data in SEQ). *The disaggregated data in SEQ show that*

(a) the distribution of FM investments is bimodal – one mode is below and one mode is above the benchmark prediction.

(b) FMs who invest less than the benchmark prediction earn less than paired SMs.

(c) FMs who invest more than the benchmark prediction earn more than paired SMs.

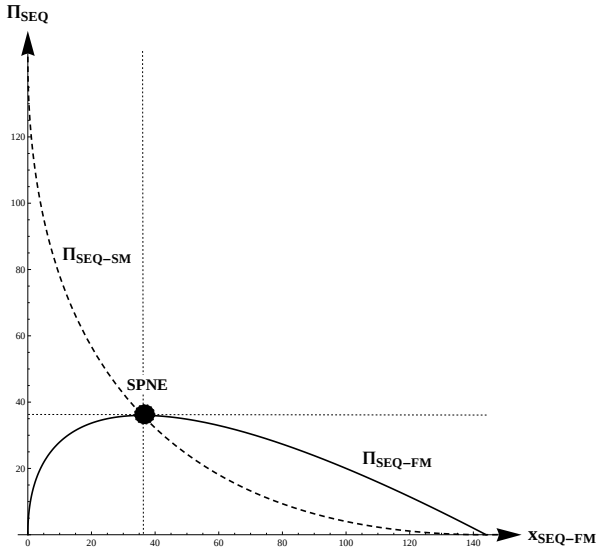
(d) FMs who invest low amounts earn significantly more than FMs who invest high amounts.

5 Explaining Observed Behavior in SEQ

5.1 Observed Behavior and the Benchmark Model

The major finding for SEQ, both in the one-shot and across repeated interactions, is that average earnings of SMs exceed average earnings of FMs in SEQ – i.e., we observe a pronounced second-mover advantage – see Result 1 and Result 3 for details. Even though this

Figure 5: FM- and SM-payoffs as a Function of FM-Investment



Note: The figure plots FM- and SM-payoffs as a function of FM investment $x_{\texttt{SEQ-FM}}$ for $M = 144$, assuming that the SM best responds to $x_{\texttt{SEQ-FM}}$.

observation is in contrast to the benchmark prediction, it should be noted that the theoretical model discussed in Section 2 may deliver a second-mover advantage when accounting for off-equilibrium behavior of FMs. We subsequently illustrate this argument.

Observed FM behavior and the Benchmark Model. Consider Figure 5 which plots FM- and SM-payoffs as a function of the FM-investment $x_{\texttt{SEQ-FM}}$, assuming that the SM chooses the investment level predicted by the standard best response, $\mathrm{BR}_2(x_{\texttt{SEQ-FM}})$. The figure reveals that the payoff of the FM is maximized if the FM invests the benchmark quantity (denoted SPNE in the figure), which is what we would expect. Moreover, the figure shows that FMs earns *less* than the paired SM if FMs invest *less* than the benchmark quantity, and *more* than the paired SM if FMs decide to invest *more* than the benchmark quantity. Interestingly, this is in line with what the disaggregate analysis reveals in both parts of the experiments, namely that FM payoffs are lower than the earnings of the paired SM if the FM invests less than the benchmark prediction, while FM payoffs are (weakly) higher than earnings of the paired SM if the FM invests more than the benchmark prediction – see Result 2 and Result 4 for details. Consequently, the fact that a majority of FMs invests less than the benchmark prediction, both in the one-shot and in repeated interactions, might explain why we observe a second-mover advantage in our experimental data. Even though this yields a reasonable explanation for the observed second-mover advantage, it does not explain *why* FMs decide to invest less than the benchmark prediction in the first place.

Accounting for SM Behavior. Table 7 provides a classification of SM behavior conditional on FM investment choices both for the one-shot and the repeated interactions.[21] It shows that off-equilibrium behavior by FMs alone is insufficient for another reason, since we also observe *systematic* deviations from the best-response investment level by SMs. In particular, the table provides the shares of SMs who invest more or less than the FM, and more or less than the best-response amount, respectively.[22] Consider first the one-shot interaction in the upper part of the table and the response of SMs to below benchmark investments by the FM. In almost 90% of these cases, SMs invest more than the FM. Given that the best-response function of SMs is above the 45-degree line for below benchmark investments by the FM – see Figure 1 – this response is qualitatively in line with the theoretical prediction. When comparing SM investments to best-response amounts, however, we find that SMs invest even more than the best-response amount most of the time, namely in 64% of all cases with below benchmark investments by the FM. The picture is similar when considering the response of SMs to above benchmark investments by the FM. Close to 92% of all SMs invest more than the best-response amount, which is below the 45-degree line for above benchmark investments by the FM, and thus below FM investments. Nevertheless, we find that SM invest even more than their paired FM in 50% of these cases. In statistical terms, we find that average SM-investment is significantly higher than the amount predicted by the standard best-response independent of whether FMs invest more (82.08 vs. 25.67; WSR: p=0.006) or less (49.46 vs. 17.99; WSR: p=0.011) than the predicted amount. Comparing the amount invested by SMs with average FM investments we find that SM choices are significantly higher than choices by FMs if FMs invest *less* (49.46 vs. 8.25; WSR: p=0.001), but not if FMs invest *more* than the predicted amount (82.08 vs. 77.42; WSR: p=0.475).

Result 5 (OS: SM-Investment Choices). *SMs invest more than the amount predicted by the own money maximizing best-response function in the one-shot – independent of FM-investment choices.*

Consider next SM behavior in part 2 of the experiment where subjects interact repeatedly – see the lower part of Table 7. Just as in the one-shot, SMs in repeated interactions invest more than the FM in response to below benchmark investments by the FM in the majority of cases. The share is much lower than in the one-shot (63.6% in REP compared to 89.3% in OS), however, and the majority of SMs invest less than the best-response amount (and not more as in the one-shot). Behavior across one-shot and repeated interactions is more similar

[21] Figure 9 provides a scatter plot of SM investment conditional on FM investment for the one-shot.

[22] We use these shares rather than averages, since mean values fail to reflect "typical" behavior in several cases due to outliers.

Table 7: SM-Behavior conditional on FM-Investment

One-Shot	Obs.	$x_{\texttt{SEQ-SM}}$ vs. $x_{\texttt{SEQ-FM}}$			$x_{\texttt{SEQ-SM}}$ vs. $x_{\texttt{BR}}(x_{\texttt{SEQ-FM}})$		
		$x_{\texttt{SM}} < x_{\texttt{FM}}$	$x_{\texttt{SM}} = x_{\texttt{FM}}$	$x_{\texttt{SM}} > x_{\texttt{FM}}$	$x_{\texttt{SM}} < x_{\texttt{BR}}$	$x_{\texttt{SM}} = x_{\texttt{BR}}$	$x_{\texttt{SM}} > x_{\texttt{BR}}$
$x_{\texttt{SEQ-FM}} < 36$	28	7.1%	3.6%	**89.3%**	25.0%	10.7%	**64.3%**
$x_{\texttt{SEQ-FM}} \geq 36$	12	25.0%	25.0%	**50.0%**	8.3%	-	**91.7%**

Repeated	Obs.	$x_{\texttt{SEQ-SM}}$ vs. $x_{\texttt{SEQ-FM}}$			$x_{\texttt{SEQ-SM}}$ vs. $x_{\texttt{BR}}(x_{\texttt{SEQ-FM}})$		
		$x_{\texttt{SM}} < x_{\texttt{FM}}$	$x_{\texttt{SM}} = x_{\texttt{FM}}$	$x_{\texttt{SM}} > x_{\texttt{FM}}$	$x_{\texttt{SM}} < x_{\texttt{BR}}$	$x_{\texttt{SM}} = x_{\texttt{BR}}$	$x_{\texttt{SM}} > x_{\texttt{BR}}$
$x_{\texttt{SEQ-FM}} < 36$	267	3.4%	33.0%	**63.6%**	**62.6%**	5.2%	32.2%
$x_{\texttt{SEQ-FM}} \geq 36$	213	**39.0%**	23.0%	38.0%	16.4%	2.8%	**80.8%**

if FMs invest more than the predicted amount. In this case, almost 81% of SMs invests more than predicted by the standard best response. Compared to the one-shot, the share of cases where SMs also invest more than the FM is lower in repeated interactions. Instead, the observation that SMs invest less than the FM is the most frequent one. We summarize this as follows:

Result 6 (REP: SM-Investment Choices). *SM behavior in repeated interactions depends on FM-investment choices:*

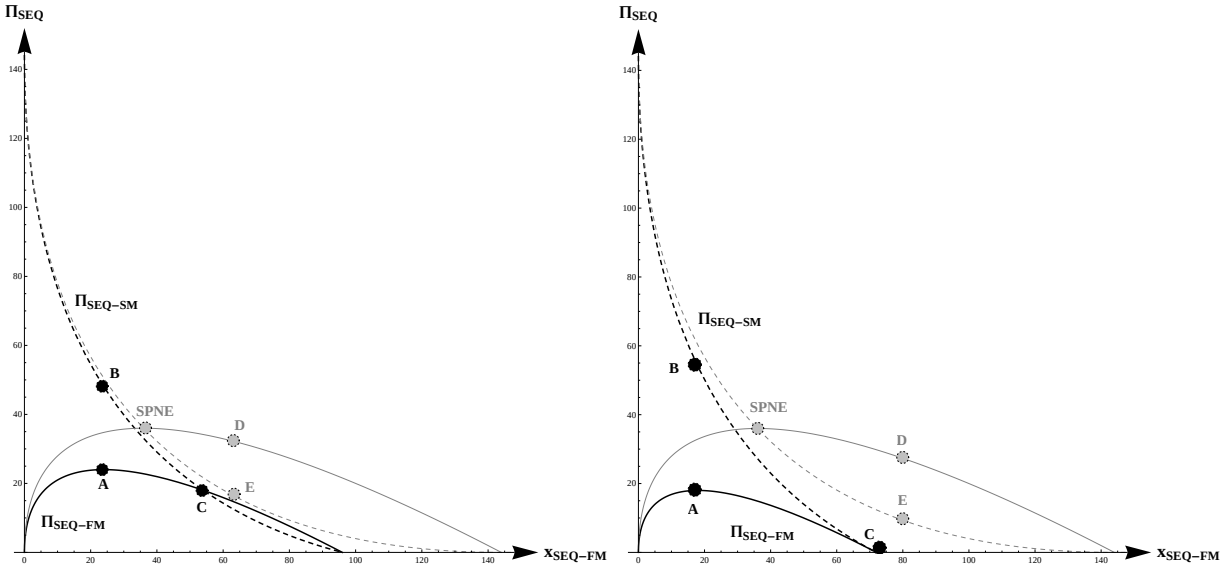
*(a) If FMs invest **more** than the benchmark amount, SMs invest **more** than the amount predicted by the own money maximizing best-response function.*

*(b) If FMs invest **less** than the benchmark amount, SMs invest **more** than the paired FM, but **less** than the amount predicted by the own money maximizing best-response function in the majority of cases.*

5.2 Observed Behavior and Other-Regarding Preferences

While above own money maximizing best-response investment by SMs is inconsistent with the benchmark model, observed SM behavior may be consistent with theories of other-regarding preferences that have already been used to explain observed behavior in related work – see Huck, Müller, and Normann (2001) or Fonseca (2009), for example. The concepts of negative reciprocity (as modelled e.g. by Rabin 1993) or inequality aversion (as modelled by Fehr and

Figure 6: FM and SM Payoffs with Relative Income Preferences



(a) $\alpha = 0.5$ (b) $\alpha = 1$

Note: Panel (a) plots FM and SM payoffs for $M = 144$ as a function of FM-investment, $x_{\texttt{SEQ-FM}}$, under the assumptions that the SM best responds to $x_{\texttt{SEQ-FM}}$, and that players might care about relative standing ($\alpha = 0.5$). Panel (b) plots the same situation as panel (a), but assumes that relative standing is more important ($\alpha = 1$).

Schmidt 1999 and by Bolton and Ockenfels 2000) both predict that SMs may be willing to sacrifice some of their own payoff to punish the FM for large investments. At the same time, these theories predict that SMs invest at most the best-response amount if the FM invests less than the theoretical prediction.[23] This is in contrast to what we observe in the one-shot. The observation that the majority of SMs invests more than the best-response amount here, independent of whether the FM invests more or less than the benchmark prediction, is in line with the relative income hypothesis by Duesenberry (1949), however.[24] To investigate in how far equilibrium predictions change in a model where both the FM and the SM potentially not only care about their absolute payoff, but also about their relative standing in comparison to the opponent, we consider a simple behavioral model in the next step and subsequently investigate in how far this model helps to organize our experimental data.[25]

[23]Note that the benchmark prediction leads to an equal division not only in `SIM` but also in `SEQ`.

[24]The crucial difference between the relative income hypothesis and the aforementioned theories of other-regarding preferences is that decision makers enjoy being ahead of others in the former – i.e., there is no reference point at the point of equal division as in the latter.

[25]Concerns for relative standings in contests may be rationalized by evolutionary game theory approaches. As shown by Guse and Hehenkamp (2006), behavior consistent with preferences of the aforementioned type follows from evolutionary stable strategies. Moreover, Leininger (2009) shows that evolutionary stable preferences turn out to be negatively interdependent.

Behavioral Model. Consider an additive comparison utility function as in Alpizar, Carlsson, and Johansson-Stenman (2005).[26] Using the same notation as in the benchmark model, the objective of firm i who competes against firm $-i$ then reads

$$\max_{x_i \geq 0} \{\Pi_i(x_i, x_{-i}) - \alpha_i \cdot \Pi_{-i}(x_{-i}, x_i)\} \ , \tag{6}$$

where $\alpha_i \geq 0$ measures the importance of relative standing as compared to absolute earnings for firm i. In particular, firm i cares exclusively about its own payoff if $\alpha_i = 0$, and instead tries to maximize the difference between own and opponent payoff if $\alpha_i = 1$. Given (6), the best-response function of firm i for investments x_{-i} by the competitor reads

$$\mathrm{BR}_i(x_{-i}) = \max\{\sqrt{(1+\alpha_i)x_{-i}M} - x_{-i}, 0\} \ .$$

Best-responses are strictly increasing in the importance of relative standing α_i, i.e., firms who care about their relative standing invest higher amounts for any given opponent investment x_{-i} than firms who focus entirely on their own payoff.

Figure 6 shows how equilibrium payoffs are affected by the parameter α_i. In particular, panel (a) plots FM and SM payoffs as a function of FM-investment , $x_{\texttt{SEQ-FM}}$, under the assumptions that the SM best responds to $x_{\texttt{SEQ-FM}}$, and that players might care about relative standing ($\alpha = 0.5$). Panel (b) plots the same situation as panel (a), but assumes that relative standing is more important ($\alpha = 1$). Consider first the point labeled 'SPNE' that is identical in both panels where the solid gray and dashed gray curve intersect. As the comparison with Figure 5 reveals, this point denotes the symmetric (subgame perfect) Nash equilibrium in the benchmark model where $\alpha = 0$ holds both for the FM and for the SM. Consider next a situation where the SM cares about relative standing ($\alpha_{\texttt{SM}} > 0$) whereas the FM does not ($\alpha_{\texttt{FM}} = 0$), and where this is common knowledge. The equilibrium payoff of the FM then decreases to **A**, while equilibrium earnings of the SM increase to **B**. Intuitively, the positive $\alpha_{\texttt{SM}}$ implies that the SM invests more than in the benchmark model for any amount invested by the FM, such that it becomes optimal for the FM to invest less than in the benchmark case. The comparison of panels (a) and (b) reveals that these changes are even more pronounced in the case where $\alpha_{\texttt{SM}} = 1$ rather than $\alpha_{\texttt{SM}} = 0.5$. Alternatively, one might assume that both the FM and the SM care about relative standing ($\alpha_{\texttt{FM}} = \alpha_{\texttt{SM}} > 0$). Compared to the benchmark model with $\alpha = 0$, concerns for relative standing induce higher investments by both the FM and the SM, such that the payoff of both firms decreases to point **C**. The comparison of panels

[26] Additive comparison utility functions are also employed by Akerlof (1997), Corneo and Jeanne (1997), and Knell (1999).

(a) and (b) again reveals that changes in payoffs are increasing in the importance of relative standing α. Finally, points **D** and **E** depict a situation where the FM cares about relative standing ($\alpha_{\texttt{FM}} > 0$), but the SM does not ($\alpha_{\texttt{SM}} = 0$) and where this is common knowledge. In particular, the figure shows that FMs earn more than SMs in this case, but slightly less than they would in the benchmark where $\alpha = 0$ holds both for the FM and for the SM.

Observed Behavior and the Behavioral Model. Consider first observed behavior in the one-shot treatment. According to the behavioral model, the reason for the observation that SMs invest higher amounts for any given opponent investment than predicted by the benchmark model is that SMs care about their relative standing – i.e., $\alpha_{\texttt{SM}}$ is strictly greater than zero for the majority of SMs. Assuming that this is the case, FMs who anticipate that SMs not only care about their absolute payoff, but also about their relative standing are predicted to invest *less* than the benchmark amount if they only care about their own absolute payoff. The observation that more than two-thirds of all FMs invest less than the benchmark prediction in the one-shot, while most SM invest more than the standard best-response amount is thus consistent with the behavioral model and delivers an outcome where FMs earn less than SMs – depicted by points **A** and **B** in Figure 6 – that we also observe in the experimental data. At the same time, the model predicts that FMs who care about their relative standing invest *more* than the benchmark amount, which can rationalize why about one-third of all FMs behaves this way in the one-shot. FMs who care about their relative standing might either earn the same amount as the SM if their paired SM cares about relative standing as well – see point **C** in Figure 6 – or more than the SM if the paired SM is exclusively interested in her own absolute payoff – depicted by points **D** and **E** in Figure 6. In line with these predictions, we observe that FMs who invest more than the benchmark amount earn (weakly) more than their paired SMs. Finally, the behavioral model predicts – in line with what we observe in the experimental data – that, given that SMs care about relative standing, FMs who invest low amounts earn significantly more in *absolute* terms than FMs who invest high amounts – a comparison of points **A** and **C** reveals that this is the case. At the same time, they are worse-off compared to their second-moving opponents in *relative* terms. In this sense, the model replicates the trade-off between absolute earnings and relative earnings for FMs that we observe in the experiment.

Expected SM-Behavior and the Behavioral Model. To investigate whether the bimodal distribution of FM investment choices can really be rationalized by the behavioral model, we subsequently investigate whether FMs who invest either above or below benchmark amounts expect the SM response we observe in the experimental data. Table 8 provides a

Table 8: Expected SM-Behavior conditional on FM-Investment

One-Shot	Obs.	$E_{\texttt{FM}}[x_{\texttt{SEQ-SM}}]$ vs. $x_{\texttt{SEQ-FM}}$			$E_{\texttt{FM}}[x_{\texttt{SEQ-SM}}]$ vs. $x_{\texttt{BR}}(x_{\texttt{SEQ-FM}})$		
		$x^E_{\texttt{SM}} < x_{\texttt{FM}}$	$x^E_{\texttt{SM}} = x_{\texttt{FM}}$	$x^E_{\texttt{SM}} > x_{\texttt{FM}}$	$x^E_{\texttt{SM}} < x_{\texttt{BR}}$	$x^E_{\texttt{SM}} = x_{\texttt{BR}}$	$x^E_{\texttt{SM}} > x_{\texttt{BR}}$
$x_{\texttt{SEQ-FM}} < 36$	28	7.1%	42.9%	**50.0%**	**71.4%**	-	28.6%
$x_{\texttt{SEQ-FM}} \geq 36$	12	16.6%	41.7%	41.7%	-	25.0%	**75.0%**

Repeated	Obs.	$E_{\texttt{FM}}[x_{\texttt{SEQ-SM}}]$ vs. $x_{\texttt{SEQ-FM}}$			$E_{\texttt{FM}}[x_{\texttt{SEQ-SM}}]$ vs. $x_{\texttt{BR}}(x_{\texttt{SEQ-FM}})$		
		$x^E_{\texttt{SM}} < x_{\texttt{FM}}$	$x^E_{\texttt{SM}} = x_{\texttt{FM}}$	$x^E_{\texttt{SM}} > x_{\texttt{FM}}$	$x^E_{\texttt{SM}} < x_{\texttt{BR}}$	$x^E_{\texttt{SM}} = x_{\texttt{BR}}$	$x^E_{\texttt{SM}} > x_{\texttt{BR}}$
$x_{\texttt{SEQ-FM}} < 36$	267	9.7%	42.3%	**48.0%**	**79.8%**	1.9%	18.3%
$x_{\texttt{SEQ-FM}} \geq 36$	213	**38.5%**	25.8%	35.7%	12.7%	4.7%	**82.6%**

classification of SM investments that FMs expect conditional on FM-investment choices both for the one-shot as well as for repeated interactions. Consider first expected SM investment of FMs who invest *more* than the predicted amount. These FMs expect above standard best-response investments by the SM in 75% (one-shot) and 82.6% (repeated) of all cases, respectively, such that expected SM investment is significantly higher than the best-response amount in both parts of the experiment.[27] In terms of the behavioral model, behavior and expectations are thus consistent with an equilibrium in which both the FM and the SM care about their relative standing; the common knowledge assumption that FMs correctly anticipate the type of competitor they are facing seems to be consistent with the data.

Consider next expected SM investments of FMs who invest *less* than the predicted amount. According to the common knowledge assumption, these FMs should expect above standard best-response investments by the SM, as the expectation of above best-response investments by the SM is necessary to rationalize below benchmark investments by FMs who only care about their own monetary payoff. This is not what we observe in the experimental data in either part of the experiment, however. While FMs who invest below benchmark amounts expect that SM investment exceeds own investment in 50% and 48% of all cases in the one-shot and across repeated interactions, respectively – implying that they expect to earn less than the paired SM – FMs expect below (rather than above) standard best-response investments by the paired SM in 71.4% and 79.8% of all cases in the respective part of the

[27] In the one-shot, we have 65.08 vs. 25.67; WSR: p=0.004; in repeated interactions, we obtain 56.02 vs. 27.90; WSR: p=0.001.

experiment – see Table 8. Said differently, expectations are in line with the mechanism that the behavioral model proposes to rationalize below benchmark investments by the FM in only 28.6% of all cases in the one shot, and in only 18.3% of all cases across repeated interactions. When using averages rather than shares, we find that expected SM investment is significantly higher than FM investment in the one-shot (27.29 vs. 8.25; WSR: p=0.003) and across repeated interactions (21.65 vs. 10.85; WSR: p=0.001), but – in contrast to what shares in Table 8 suggest – slightly above the amount that maximizes profits of the SM in the one-shot (27.29 vs. 17.99; WSR: p=0.244), and close to this amount in repeated interactions (21.64 vs. 20.92; WSR: p=0.201).

Taken together, the behavioral model is capable to rationalize SM investment behavior observed in the experiment under the assumption that SMs not only care about their own absolute payoff, but also about their relative standing vis-à-vis the FM. Moreover, the behavioral model can explain outcomes where both the FM and the SM invest more than predicted by the standard model. The behavioral model is less successful in explaining why FMs invest less than the standard model predicts. In particular, SM investment expected by FMs lends little support to the mechanism that the behavioral model proposes to rationalize below benchmark investments by FMs. Expectations instead suggest that FMs invest "too low" amounts to establish collusion, and not because they expect above best-response investment by the SM independent of the amount invested by the FM as suggested by the behavioral model.

5.3 Observed Behavior and Collusion

FM expectations suggest that many FMs expect to establish a collusive outcome in which they invest less than the benchmark prediction, and the paired SM responds by investing less than the own profit maximizing best-response amount. In particular, this is what 71.4% of all FMs who invest less than the benchmark prediction expect in the one-shot. In the repeated interactions, the corresponding value is close to 80.0% of all cases – see Table 8 for details. As discussed above, we find little evidence that SMs respond to attempts to establish collusion in the one-shot, where close to two-thirds of all SMs invest even above best-response amounts in these cases. This is very different in part 2 of the experiment where subjects interact repeatedly. Here, SMs invest *less* (and not more) than the standard best-response amount in response to below benchmark investments by the FM in the majority of cases – see the lower part of Table 7 for details. Said differently, there is strong evidence for collusion in part 2 of the experiment where subjects interact repeatedly, but little in part 1 where subjects interact

only once.[28] This is well in line with findings in many other experimental studies where fixed pairs interact repeatedly and manage to collude – even though the number of repetitions is predetermined and finite – while collusion is hardly ever observed in a one-shot interaction or in repeated interactions with random rematching. In contrast to most previous findings, however, we observe that collusive outcomes in repeated interactions are often asymmetric favoring the SMs, and that this is even anticipated by many FMs. In particular, SMs invest more than a FM who makes a collusive offer in almost two-thirds of all cases according to Table 7, and close to 50% of FMs who invest less than the benchmark prediction anticipate this – see Table 8. Said differently, many FMs expect a cooperative response (=below best-response investment) by their paired SM, but they also expect that SM investment exceeds FM investment, implying that the SM earns more than the FM.

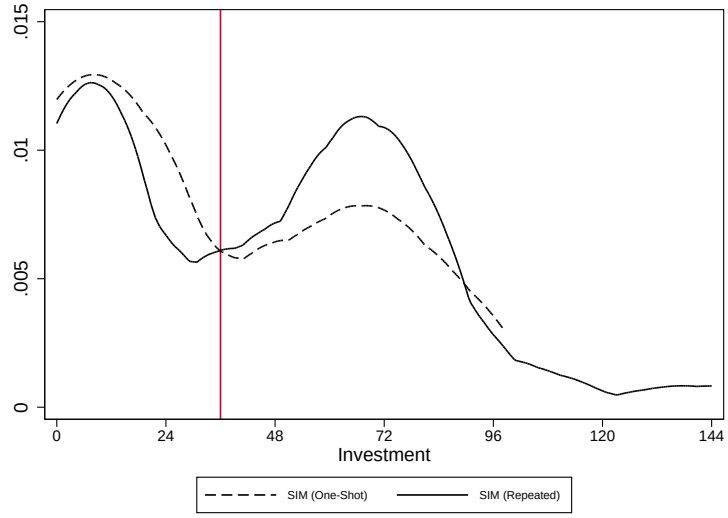
6 Discussion

Evidence on investment choices and expectations suggest that two aspects are important to explain deviations from the theoretical benchmark and the resulting outcomes in treatment `SEQ`: First, most SMs as well as those FMs who invest more than the predicted amount seem to care about relative standing, and not exclusively about their own monetary payoff. Second, the observation that many FMs invest less than the predicted amount and expect their paired SM to respond by investing less than the own profit maximizing best-response amount indicates that these FMs intend to establish a collusive outcome. While both these aspects are important to jointly account for FM and SM behavior and the resulting outcomes in `SEQ`, it is worth mentioning that the concern of SMs for relative standing alone is sufficient to explain the second-mover advantage we observe in both parts of the experiment. In particular, SM investment choices in the one-shot ensure that FMs who invest low amounts are much worse-off than their paired SM, but still better-off in absolute terms than FMs who invest high amounts. Similarly, behavior of SMs in repeated interactions implies that SMs receive (much) higher payoffs on average than FMs who try to establish collusion, but corresponding choices of SMs in response to high FM investments ensure that these FMs are worse-off than those who invest low amounts.[29] Consequently, the power of the SM to ultimately determine relative payoffs through the own investment choice allows SMs to

[28] In more than 10% of all cases in part 2, the FM and the SM even coordinate on investing zero or one, respectively.

[29] Importantly, the similarity between random and fixed effect regressions in Table 6 shows that the within-subject response is almost identical to the between subject response. Said differently, we indeed observe that FMs who change their investment choice across the course of repeated interactions in part 2 of the experiment face the trade-off between absolute earnings and relative standing due to the corresponding reaction of their paired SM.

Figure 7: Density Function Investment Choices in SIM



Note: The figure approximates the distribution of investment in treatment SIM, using an Epanechnikov kernel estimator with the optimal bandwidth.

enjoy a second-mover advantage and implies that FMs face a trade-off between absolute and relative earnings.

Given that we had to extend the standard model to explain observed outcomes and choices in treatment SEQ, it is somewhat surprising that average outcomes and investment choices in treatment SIM appear to be in line with the benchmark prediction in both parts of the experiment. Intuitively, one should expect that subjects in SIM have the same preferences as those in SEQ. In particular, it seems natural to presume that some subjects in SIM care about relative standing, while others try to establish collusive outcomes. Interestingly, a disaggregate analysis of investment choices in SIM reveals that behavior across SIM and SEQ is similar in its deviations from benchmark predictions, in contrast to what averages suggest. For the sake of brevity, we restrict attention to the one-shot in what follows, as behavior is qualitatively similar across parts 1 and 2 in SIM – as revealed by Figure 7, for example.[30] The figure plots the density of investment choices in SIM in the one-shot as well as across all repeated interactions and reveals that investment choices are bi-modal. In particular, investment choices appear to be concentrated below and above, but not around the benchmark prediction in both parts of the experiment – just as for FMs in SEQ. When accounting for expectations, we cannot reject the hypothesis that subjects who invest more than predicted expect their opponents to invest similar amounts in the one-shot (WSR: p=0.534). This is consistent with the behavioral model if we are willing to assume that decisions makers who care about relative standing expect their opponents to care about relative standing as well. Importantly, the fact that expectations of decision makers who invest more than predicted

[30]Details are available from the authors upon request.

are similar across treatments SIM and SEQ makes it unlikely that the response of SMs to high investments by the FM can be interpreted as 'punishment' or negative reciprocity, since players in the one-shot version of SIM cannot strategically react to off-equilibrium opponent investment. Expectations of subjects who invest less than predicted in the one-shot version of SIM suggest that they expect a collusive opponent, as expected opponent investment is significantly below the best-response (WSR: p=0.008). While this is similar in SEQ, expectations of subjects who invest below benchmark amounts also reveal an important difference across SIM and SEQ. While FMs in the one-shot version of SEQ expect to earn less than the paired SM (46.28 vs. 62.19; WSR: p=0.022), subjects in the one-shot version of SIM seem to expect to earn at least the same as the opponent (71.56 vs. 47.48; WSR: p=0.207).[31] This observation again illustrates the importance of the SM's power to ultimately determine relative payoffs through the own investment choice for the second-mover advantage we observe in SEQ, as similarly behaving subjects in SIM and SEQ expect and receive different payoffs: While subjects in SIM seem to hope that their opponents invest even less than they did, FMs in SEQ anticipate that SMs have the power to secure themselves a higher payoff – even though they underestimate the amount actually invested by SMs as discussed above.

7 Concluding Remarks

The findings of this paper suggest that moving second is an advantage in strategic interactions even if strategic first-mover or second-mover advantages are absent in the theoretical benchmark. A crucial difference between simultaneous-move and sequential-move games is that both players face the same strategic uncertainty in the former, but not in the latter where FMs do face strategic uncertainty, while SMs do not. In particular, in sequential-move games observing FM investments gives SMs the power to ultimately determine relative and absolute payoffs through their investment choice. While this power is arguably most valuable in the presence of FMs who try to establish collusion, it is important to note that SMs are able to ensure that they earn more than FMs even if FMs invest the predicted amount. Said differently, below benchmark investment by FMs is necessary for a positive value of information, but the concern for relative standing vis-à-vis the FM alone is sufficient to observe a second-mover advantage.

It is worth noting that our findings might help to explain why the empirically observed first-mover advantage in previous experimental work by Huck, Müller, and Normann (2001) is quantitatively smaller than predicted by the quantity-competition model, while the second-

[31] The expected payoff is not directly elicited in the experiments, but can be computed. In particular, we use own investment and expected opponent investment to infer the expected payoff.

mover advantage that Kübler and Müller (2002) observe in their experiments is larger than predicted by the price-competition model. Even though this evidence seems to suggest that the inherent advantage to move second isolated in this paper works on top of strategic implications in other settings, we believe that it is an interesting question for future work to investigate in more detail how the inherent advantage to move second interacts with strategic first- or second-mover advantages in the theoretical benchmark.

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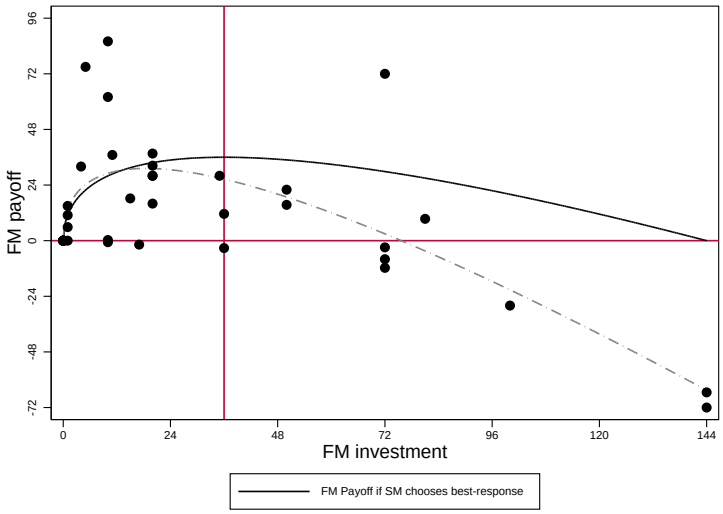
Appendix

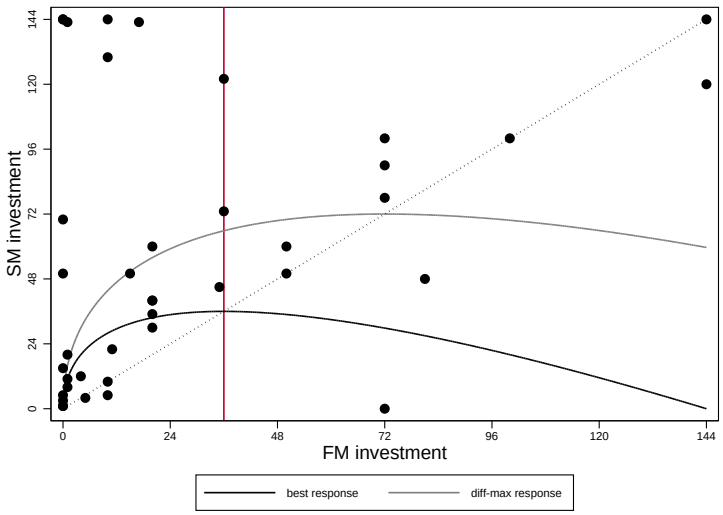
A Additional Material

Figure 8: Relation between FM-Investment and Payoff in `SEQ` (OS)



Note: The figure plots FM-payoffs as a function of FM investment, as well as the functional relationship between the respective payoff and FM investment if the SM invests the best-response amount. The gray dashed lines provide the estimated functional relationship, using the estimation equation $\pi_{\texttt{FM}} = \beta_0 + \beta_1 * \sqrt{\text{INV}_{FM}} + \beta_2 * \text{INV}_{FM}$.

Figure 9: SM Investment conditional on FM investment in `SEQ` (OS)



Note: The figure plots SM investment as a function of FM investment, the 'own money maximizing' best-response function, and the relative payoff maximizing best response function.

B Experimental Instructions

The experimental instructions consist of three parts: First, subjects receive some general information about the experimental session. Then, they are informed about the first part of the experiment. After completing the first experiment (one-shot interaction) they are informed on the computer screen about the second part of the experiment (repeated interaction). After completing these two experimental parts they receive the instruction for part 3 and part 4 which are unrelated experiments and thus instructions are not presented here. We present the experimental instructions for both the simultaneous and sequential game in one document since the only thing which changed was the description of the timing of the game.

WELCOME TO THIS EXPERIMENT AND THANK YOU FOR YOUR PARTICIPATION

General Instructions:

You will participate in 4 different experiments today. Please stop talking to any other participant of this experiment from now on until the end of this session. If you have a question please raise your hand, we will come to your seat.

In each of the 4 experiments, you will have to make certain decisions and may earn an appreciable amount of money. Your earnings will depend upon several factors: on your decisions, on the decisions of other participants, and on random components, i.e. chance. The following instructions explain how your earnings will be determined.

The experimental currency is denoted **Taler**. In addition to your Taler earnings in the experiments 1-4, you receive 4 EURO show-up fee. You may increase your Taler earnings in all experimental parts, where 1 Taler equals 2 Euro-Cent, i.e.

50 Taler correspond to 1 Euro.

At the end of this experimental session your Taler earnings will be converted into Euro, rounded to 10 Cent and paid to you in cash.

All your decisions in this experiment will be entered in a mask on the computer, the same holds for all other participants of the experiment. In addition, the computer will determine the random components which are needed in some of the experiments. All data collected in this experiment will be matched to your participant number, **not** to your name or student number. Your participant number will also be used for payment of your earnings at the end of the experimental session. Therefore, your decisions and the information provided in the experiments are completely anonymous; neither the experimenter nor anybody else can match these data to your identity. In the experiments you are matched with other participants of the experiment, this is done randomly and completely anonymous through the computer and you and your partner are not informed about each others identity.

We will start with experiment 1, followed by the other experimental parts.

You will receive your earnings in cash at the end of the experimental session.

Experimental Part 1

In this experiment you and a randomly assigned other participant of the experiment decide about the distribution of a prize. You can be either 'Type A' or 'Type B'. You will be informed about your type on the computer screen right before the start of the experiment. You will always be matched with a person which has the opposite type than you.

Your Decision

You and the matched person receive an initial endowment of 144 Taler. The endowment can be used to invest a certain amount between 0 and 144 Taler. The distribution of the prize of **144 Taler** is determined by your investment and the investment of the other person:

$$\textbf{Your Share} = \frac{\text{Your Investment}}{\text{Your Investment} + \text{Investment of the matched person}} = \frac{\text{Your Investment}}{\text{Total Investments}}$$

Thus, the share of the prize you get is equal to the share of your investments in relation to total investments. At the same time the share of your matched person is the share of his/her investments in relation to total investments.

The share of the prize you get is higher

- the more you invest
- the less the matched person invests

If both invest the same amount then the prize will be shared equally between you and your partner, meaning that

$$\textbf{Your Share} = \textbf{Share of the matched person} = \frac{1}{2}$$

This sharing rule also applies in the case both players invest an amount of 0.

Your Payoff

Your payoff is determined by the initial endowment minus the amount you invested plus the share of the prize you receive. Suppose you invest amount $\boldsymbol{X_1}$, whereas the matched player invests $\boldsymbol{X_2}$. Then your payoff is determined as follows:

$$\begin{aligned}\textbf{Payoff} &= \text{Endowment} - \mathbf{X_1} + \frac{\mathbf{X_1}}{\mathbf{X_1} + \mathbf{X_2}} * \text{Prize} \\ &= 144 \text{ Taler} - \mathbf{X_1} + \frac{\mathbf{X_1}}{\mathbf{X_1} + \mathbf{X_2}} * 144 \text{ Taler}\end{aligned}$$

An increase of investment $\boldsymbol{X_1}$ has therefore two effects:

- You receive **less** from your initial endowment
- The share of the prize is **increased**, given investment $\boldsymbol{X_2}$ of the other player

Timing [SIM Interaction]

1. You and the matched person receive an initial endowment of 144 Taler.
2. You and the matched person invest simultaneously an amount between 0 and 144 Taler.

    - When you decide about the amount you invest, you do not know how much the other person invests.
    - At the same time, the other person does not know how much you invest.

3. You receive information about the investment of the matched person, your payoff and the payoff of the matched person.

Timing [SEQ Interaction]

1. You and the matched person receive an initial endowment of 144 Taler.
2. You and the matched person invest **one after another** an amount between 0 and 144 Taler.

    - When you decide about the amount you invest first, you do not know how much the other person invests.
    - When you decide about the amount you invest secondly, you are informed about the amount invested by the other player, **before** you decide about your own investment.

    Before the experiment starts you will be informed on the computer screen when you have to make your decision.

3. You receive information about the investment of the matched person, your payoff and the payoff of the matched person.

Training programme

Before we start with the experimental part 1 you have the possibility to train your understanding of the instructions with a training programme on the computer. In this training programme you can freely decide about your investments and the investments of a hypothetical partner. You will then be informed about your payoff and the payoff of this hypothetical partner. You can repeatedly choose different numbers for the investments.

We will start the training programme immediately.

Questions

If you have any questions until now or when there show up questions during the training programme, please raise your hand and we will come to your seat to answer the question.