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A "More-is-Better" heuristic in anticommons dilemmas: Psychological insights from a new anticommons bargaining game

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ABSTRACT

In the present paper, we investigate how people make decisions when bargaining about complementary resources. When the ownership of such resources is fragmented, actors often fail to coordinate on efficient access, leading to an overall loss in social welfare; the tragedy of the anticommons. In a series of three experiments, in which we introduce a newly developed Anticommons Bargaining Game, we show that people tend to treat perfectly complementary resources as if they are non-complementary. Specifically, we demonstrate that both sellers and buyers of such resources used a more-is-better heuristic when determining their prices. That is, sellers who initially owned a larger part of the resource asked a higher price for their resource than sellers with a smaller part, even though only the combination of parts generated value for the buyer. Likewise, buyers offered more money to sellers with a larger part than to sellers with a smaller part. While this heuristic does not necessarily impede coordination, inequality in resources led to unequal monetary outcomes between the two sellers.

The conflict between the individual and collective interest is considered the root cause of collective action problems (Ostrom, 1990), and is generally referred to as a social dilemma. The scientific study on such social dilemmas has expanded rapidly in the last decades (for overviews, see e.g., Dawes, 1980; Van Lange, Parks, & Van Dijk, 2013; Van Lange & Rand, 2022). A widely studied example is the commons dilemma, in which a group of individuals have unlimited access to a scarce collective resource, such as oil, gas or water (Ostrom, 1990). When the people involved are mainly motivated to further their self-interest, it leads to overuse, and sometimes even depletion of the collective resource (Hardin, 1968; Ostrom, 1990). Hardin (1968) famously termed this phenomenon the "Tragedy of the Commons". Real-world examples of such "tragedies" are overfishing, drought due to water overuse, and the depletion of fossil fuels (e.g., oil or gas). The mirror-image of the commons dilemma, that has received much less research attention, is the anticommons dilemma (Michelmann, 1982). In this dilemma, individuals own resources that are complementary to one another, and that – only if combined – generate benefits for the collective. In the present paper, we investigate how the size or quantity of such complementary resources affects their pricing, people's bargaining decisions and outcomes in anticommons dilemmas. We show that sellers as well as buyers are highly influenced by differences in quantity, even when resources are perfectly complementary and only yield value when combined. Results suggest that people apply a "more-is-better" heuristic, a decision rule that is appropriate for standard, non-complementary goods, but is less meaningful for complementary goods.

Whereas in the commons dilemma collective inefficiency results from individuals having unlimited access to a common resource (De Geest, Kidwai, & Portillo, 2022), in the anticommons dilemma individuals can limit others' access to resources. As an example,

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Heller and Eisenberg (1998) presented the case of gene patents in the biotech industry. From the 1970s onwards, tens of thousands of DNA-related patents were granted to hundreds of different biotech companies. As a consequence, companies that wanted to develop DNA-based diagnostic tests first had to acquire access to several patented areas of one chromosome, which were often owned by several different patent holders. As one can imagine, having to make deals with different patent holders can slow down innovation and can potentially even prevent treatments for diseases from being developed, which is detrimental to the collective interest. Whereas commons dilemmas can lead to overuse of a resource, anticommons dilemmas can thus lead to underuse. Heller (1998, 2013) termed such underuse the "Tragedy of the Anticommons". Underuse of biomedical patents is not the only real-life example of such a collective tragedy. Anticommons dilemmas have been identified in various other settings and across different centuries (for many examples, see Heller, 2008). Real-world examples range from medieval toll castles at the German Middle-Rhine, where lords collected tolls from merchants to pass their part of the trade route (Gardner, Gaston, & Masson, 2002), to patent infringements lawsuits in the smartphone industry (Yang, 2014).

To explain decision-making in anticommons dilemmas it is important to understand the two unique features that distinguish them from other types of social dilemmas: (a) they involve complementary resources and (b) the ownership of these complementary resources is fragmented. Complementary resources are resources that add value to one another. In some cases, resources are even perfectly complementary, such that one of them is worthless without the other (Mankiw, 2008; Newman, 2008). For instance, the patent for a touch screen is useless on its own, but – in combination with other technological patents – is essential for the functionality of a smartphone or tablet. If all these patents would be in the hand of the same owner, this would not be problematic. The anticommons problem, however, emerges when the ownership of such resources is fragmented, with different agents owning different complementary resources. Fragmented ownership not only complicates matters by increasing the number of transactions needed and agents involved. Importantly, it can result in underuse of these resources and thereby be detrimental to the collective welfare. Such underuse occurs when the owners of complementary resources ask a higher price than potential buyers are willing to pay. As a result, overpricing might even prevent new products, like life-saving medicines, from being developed at all (Heller, 1998; Heller & Eisenberg, 1998).

Surprisingly, however, empirical research on the factors that lead to overpricing and underuse in anticommons dilemmas has been scarce (for exceptions, see Dhont, Van Hiel, & De Cremer, 2012; Glöckner, Tontrup, & Bechtold, 2015; Van Hiel, Vanneste, & De Cremer, 2008; Vanneste, Van Hiel, Parisi, & Depoorter, 2006). One of the few empirical papers on this topic (Dhont et al., 2012) showed that a reason why individual sellers ask too high a price for their commodity in anticommons dilemmas is that the detrimental consequences of overpricing for the collective are not salient enough to them. After all, their pricing decisions do not directly hamper an existing resource (like in commons dilemmas); overpricing primarily impacts potential outcomes that have not yet been realized. Put differently, in anticommons dilemmas – as compared to commons dilemmas – people may be less aware of the collective externalities of non-cooperation (Dhont et al, 2012). Relatedly, Alvisi and Carbonara (2013) argued that in anticommons dilemmas, owners determine their selling prices for their own resource without considering the negative externality imposed on the sellers of other complementary resources. The above insights suggest that sellers may treat their individually owned resources as if they are not complementary to the resources of other owners. Yet, how exactly sellers then determine the value of their resources and how this relates to the tragedy of the anticommons has not been investigated.

In the present paper, we empirically test how the size or quantity of complementary resources influence individuals' valuation of such resources and investigate what role these characteristics play in the anticommons dilemma. For this purpose, we developed a new experimental anticommons paradigm, that we modeled after the complementary patents example we presented earlier. In this paradigm – which we term the Anticommons Bargaining Game – three persons are involved: two Sellers and one Buyer. The two Sellers (1 and 2) each have a part of a jigsaw puzzle in their possession, and both parts together constitute a complete puzzle. The aim of the Buyer is to purchase the complete puzzle from the two Sellers, as only a complete puzzle creates a value for the Buyer. The Buyer can try to make a deal with the two Sellers by offering each of them points worth money (i.e., indicating their Willingness to Pay; WTP). The Sellers can, at the same time, indicate how many points they would like to receive for their part of the puzzle (i.e., their Willingness to Accept; WTA). If the number of points offered to Seller 1 is equal to or higher than the number asked by that Seller, a deal is made between Seller 1 and the Buyer. In that case, Seller 1 sells her part of the puzzle to the Buyer, and the Buyer pays the Seller's asking price. The same applies to Seller 2 and the Buyer. Sellers can only obtain points by making a deal with the Buyer. The Buyer only obtains a monetary bonus if she manages to obtain the full puzzle from the two Sellers. If the Buyer only makes a deal with one of the Sellers (or with none of them), the puzzle is not complete, and the Buyer does not obtain a monetary bonus. Thus, the two parts of the puzzle are perfectly complementary, as one part is worthless without the other. Moreover, if the Buyer does not make any deal with the two Sellers, they all receive a zero payoff, as the puzzle pieces are not sold and the full potential of the puzzle is not realized (i.e., an anticommons tragedy).

A strength of our newly developed Anticommons Bargaining Game is that we can easily vary the size or quantity of the complementary resource individuals bargain about (i.e., the number of puzzle pieces each Seller has). The size or quantity is a characteristic that would be highly relevant if one would bargain about a non-complementary resource, but that in a setting with perfectly complementary resources should be irrelevant. Consider, for example a setting where one Seller initially owns 3 puzzle pieces of a 4-piece puzzle, whereas the other Seller owns only 1 puzzle piece. Because the Buyer can only realize the collective benefit by acquiring the entire puzzle, and ending up with only one part of the puzzle is worthless (regardless of whether the Buyer ends up with 1 or 3 out of the 4 pieces), it would be straightforward to assume that the Buyer assigns the same value to each part of the puzzle, since the one part is useless without the other. If Sellers realize this, they should consequently also ask for a similar prize that reflects this complementarity of the two resources for the Buyer. In our paradigm with perfectly complementary resources, the number of initially assigned puzzle pieces should thus be an irrelevant characteristic for both Sellers and Buyer. Note, however, that the size or quantity of a resource would be relevant if the resources are non-complementary. After all, the value of a non-complementary resource tends to increase with its size or quantity (e.g., like in the case of land, bread or water). If Sellers indeed tend to overlook the fact that resources are complementary – as previous researchers suggested (Alvisi & Carbonara, 2013) – they might base their selling prices on the number of pieces they own; those with more pieces would set higher selling prices (WTA) than those with fewer pieces. If Buyers' decisions would follow the same line of reasoning, they would also make higher offers (WTP) to Sellers with many pieces than to Sellers with few pieces. In other words, if Buyers and Sellers indeed use such a "more-is-better" heuristic, this would fit with the suggestion that it is difficult for people to grasp the implications of fragmentized complementary resources. Moreover, our newly developed anticommons paradigm also allows us to test whether inequality in resources might be one potential mechanism underlying underuse in the anticommons dilemma.

Hypotheses. Based on the above reasoning, we predict that Sellers with many puzzle pieces set higher selling prices than Sellers with few puzzle pieces (Hypothesis 1). This implies that the difference between the WTAs of Sellers 1 and 2 should become larger the larger the Inequality between them (operationalized as the number of puzzle pieces they own).

We also predict that Buyers will make higher offers to Sellers with many puzzle pieces than to Sellers with few puzzle pieces (Hypothesis 2). This implies that the difference between the Buyer's WTPs to Sellers 1 and 2 should become larger the larger the Inequality between them (in number of puzzle pieces they own).

In addition to testing these hypotheses, the Anticommons Bargaining Game also allows us to test under which circumstances (i.e., Equality versus Inequality) overpricing and underuse of complementary resources tend to occur most frequently. Under Equality (i.e., both Sellers own the same number of pieces), a salient focal point or heuristic is to simply pay and ask for the same price across Sellers. This would also align with the logic of complementary resources – both parts of the puzzle are equally valuable, if obtained. Thus, under Equality such a heuristic should enable effective coordination on prices and successful trading, and (thereby) reduce the probability of a tragedy of the anticommons.

In contrast, under Inequality, it might be that the Seller with many puzzle pieces may be inclined to ask a higher price than the Buyer is willing to pay. This may primarily occur if the tendency to overlook the complementarity (and apply a more-is-better heuristic) is stronger for Sellers than for Buyers. After all, Sellers only have to set a price for their own part of the puzzle, while Buyers have to consider both parts at the same time and might therefore be more aware of the complementarity involved. Furthermore, there is also uncertainty between Sellers and Buyer on how more pieces should be priced exactly, since each individual piece has no intrinsic value. Hence, even if Buyers and the Seller share a more-is-better heuristic, they are still confronted with the problem of how to exactly value the unequal distribution of puzzle pieces across Sellers. This disparity and uncertainty in price-setting between Buyers and Sellers, might then lead to more underuse under Inequality compared to Equality (which we can analyze by looking at the frequency at which the full puzzle is not obtained by the Buyer, i.e., their failure rates).

Given the uncertainty and possible differences in price setting (especially under Inequality), we let Buyers and Sellers play our Anticommons Bargaining Game repeatedly with full feedback in between rounds. This allowed us to explore whether groups learn to better coordinate their decisions over time (cf. Diekmann & Przepiorka, 2016; Przepiorka, Bouman & De Kwaadsteniet, 2021), become more aware of the complementarity of the resources as the game progresses, and whether their initial use of pricing heuristics (e.g., a more-is-better heuristic) diminishes in later rounds.

1. Study 1

1.1. Method

Sample Size. For all studies in this paper, we aimed to recruit a minimum of 60 participants per condition. This desired sample size was chosen such that we would have at least 20 strictly independent observations (i.e., groups) per treatment, which is in line with previous, related studies (Guido, Robbett, & Romaniuc, 2019).

Participants and Design. For Study 1, which was advertised as a study on "social decision making", we recruited 123 participants (28 males, 95 females, $M_{\text{age}} = 22.96$, $SD_{\text{age}} = 5.17$). For their participation in this study, which took approximately 15 to 20 min to complete, they received 2 euros (or 1 course credit) plus the amount of money they earned in the Anticommons Bargaining Game. The study had a between-subjects design with 2 treatments (Equality vs. Inequality).

Procedure. Upon arrival at the laboratory, participants were seated in separate cubicles, each containing a computer that was used to give instructions and to register their responses. Next, they were randomly assigned to groups of three. Subsequently, these 3-person groups were randomly assigned to either the Equality or Inequality condition. In the Equality condition we had 22 groups in total, and in the Inequality condition we had 19 groups in total. Before running our studies, the procedures were approved by the Ethics Review Board of the first author's Department.

The Anticommons Bargaining Game that the 3-person groups were presented with was called a "puzzle-pieces task" in the instructions (for the full instructions, see the Supplementary Materials). The task was programmed by the first author using the open-source program oTree (Chen, Schonger, & Wickens, 2016). Participants learned that they would perform the puzzle-pieces task over 20 consecutive rounds together with two other participants, who were seated in a similar cubicle as themselves. Participants were informed that they could earn points in this task and that these points were worth real money, namely 1 euro per 100 points. Participants were also told that all the points they would earn across rounds would be added up and paid out at the end of the experiment.

The structure of the puzzle-pieces task was as follows: two of the participants were randomly assigned to the role of Seller (i.e., Seller 1 and Seller 2), and one participant was randomly assigned to the role of Buyer. Roles remained the same across all rounds. At the start of each round, the two Sellers, each, had a part of a four-piece puzzle in their possession. Each Seller could try to earn points by selling her own part of the puzzle to the Buyer. In every round, each Seller would indicate how many points she minimally wanted to receive for her own part of the puzzle (Willingness to Accept or WTA, see e.g., Horowitz & McConnell, 2003). In other words, Seller 1 would determine a WTA for her own puzzle pieces (WTA_1), and, at the same time, Seller 2 would set a WTA for her own puzzle pieces (WTA_2).

The Buyer would start each round with 20 points. She could keep these points for herself, or she could use these points to try to buy the puzzle from the two Sellers. To obtain the puzzle, the Buyer had to indicate how much she was maximally willing to pay for Seller 1′s part of the puzzle (Willingness to Pay: WTP_1), and how much she was maximally willing to pay for Seller 2′s part of the puzzle (WTP_2). Only if WTP_1 would be at least as high as WTA_1, a deal would be made between the Buyer and Seller 1 (and her puzzle pieces would be sold for WTA_1). Likewise, only if the WTP_2 would be at least as high as WTA_2, a deal would be made between the Buyer and Seller 2 (and her puzzle pieces would be sold for WTA_2).

In each separate round, the payoff π of each Seller x can be formally described as follows:

$$\pi_{\text{Seller x}} = \begin{cases} WTA_x & \text{if } \; WTP_x \geq WTA_x \\ 0 & \text{if } \; WTP_x < WTA_x \end{cases}$$

Hence, it is always better for each Seller to sell her part of the puzzle than to keep it. Importantly, the payoff function remains the same regardless of how many individual pieces a Seller has in her possession. In other words, the number of puzzle pieces is not associated with any intrinsic value for the Sellers and therefore is not part of their payoff function.

Since puzzle pieces are perfectly complementary, the Buyer can *only* obtain a monetary bonus in each round if she manages to make a deal with both Sellers. That is, only if the Buyer manages to obtain the complete puzzle, she earns an additional monetary bonus of 20 points. An incomplete puzzle is worthless for the Buyer. In each round, the payoff of the Buyer can be formally described as:

$$\pi_{\text{Buyer}} = \begin{cases} 20 - WTA_1 - WTA_2 + 20 & \text{if } \; WTP_1 \geq WTA_1 \text{ and } \; WTP_2 \geq WTA_2 \\ 20 - WTA_1 & \text{if } \; WTP_1 \geq WTA_1 \text{ and } \; WTP_2 < WTA_2 \\ 20 - WTA_2 & \text{if } \; WTP_1 < WTA_1 \text{ and } \; WTP_2 \geq WTA_2 \\ 20 & \text{if } \; WTP_1 < WTA_1 \text{ and } \; WTP_2 < WTA_2 \end{cases}$$

From the above, it is clear that the Buyer should strictly prefer not buying any parts to buying only one part. Hence, in the case of a four-piece puzzle, it is always better to not buy any pieces (and keep one's 20 points) compared to buying 1, 2, or 3 pieces (and earn 20 points minus the cost of obtaining only one part of the puzzle). Whether the Buyer obtains a large or small part of the puzzle is irrelevant for her payoff – quantity is not part of the payoff function. A 'more-is-better' logic only applies to the edge-case, when comparing zero parts to obtaining the complete puzzle. For a complete puzzle, the Buyer can make a net profit, if the price she pays for it ($WTA_1 + WTA_2$) is smaller than the monetary bonus (20 points).

Before starting with the first round of the Anticommons Bargaining Game, six multiple-choice comprehension check questions were posed (see Supplementary Materials), which were designed to check whether the participants had understood the rules of the task. Only after all six questions were answered correctly, participants could proceed to the first round of the task. In between rounds, the Sellers and Buyer learned what the WTA's and WTP's in the previous round had been, which deals had been made, and how much each had earned in that round. After all 20 rounds of the task were finished, we additionally posed 8 Likert-scale questions, which were intended to explore the motives underlying the participants' decisions. For instance, we asked participants to what extent they thought they deserved more points than the other players, and to what extent they had tried to make fair decisions (see Supplementary Materials, for the exact questions).

After completing the whole study, participants were paid, thanked for their participation, and debriefed about the content and purpose of the study.

The Experimental Treatments: Equality versus *Inequality*. The 3-person groups were randomly assigned to one of two treatments: Equality versus Inequality. In both treatments, groups performed the exact same Anticommons Bargaining Game with the identical

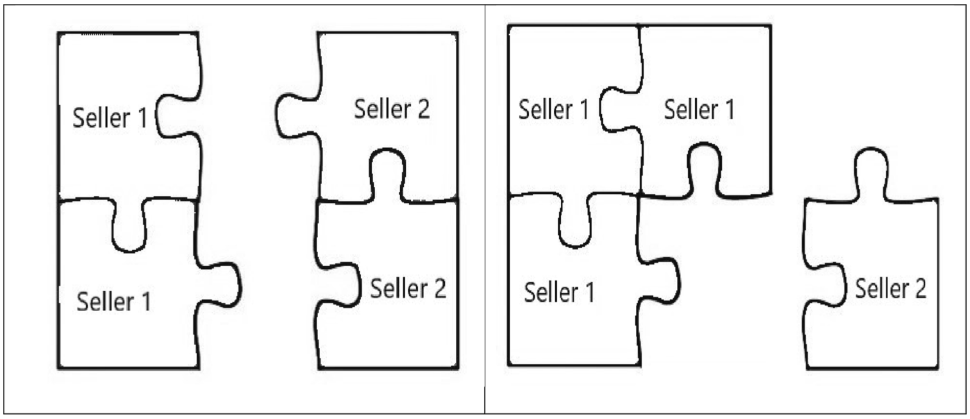

Fig. 1. Study 1 – Graphical Representations of the Puzzle Pieces in the Equality (left) vs. Inequality Condition (right).

payoff structure as described above. The two treatments only differed in the number of puzzle pieces that each Seller had at the beginning of each round.

In the Equality condition, each of the two Sellers (i.e., Seller 1 and 2) started each round with 2 puzzle pieces. This was explained to participants using a graphical representation of a 4-piece puzzle (see Fig. 1). In the Inequality treatment, by contrast, Seller 1 started each round with 3 pieces, whereas Seller 2 started with 1 piece. Yet, in both treatments, the puzzle pieces of Sellers 1 and 2 were perfectly complementary, and only if the Buyer would make a deal with both Sellers, she would earn the monetary bonus of 20 points.

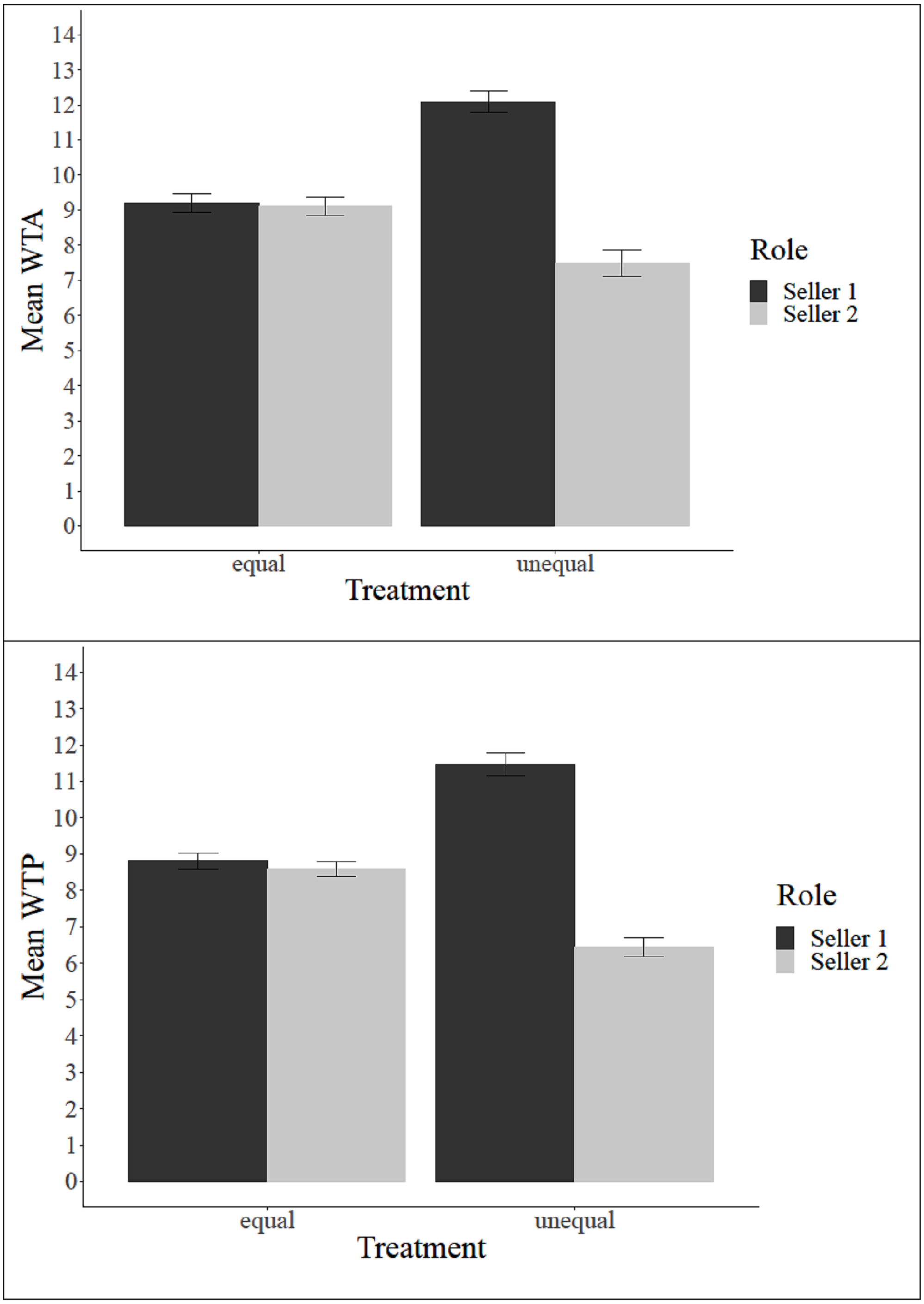

Fig. 2. Study 1 - Mean Willingness to Accept (WTA, top) and Willingness to Pay (WTP, bottom) per Seller Number (1 vs. 2) and Treatment (Equality vs. Inequality).

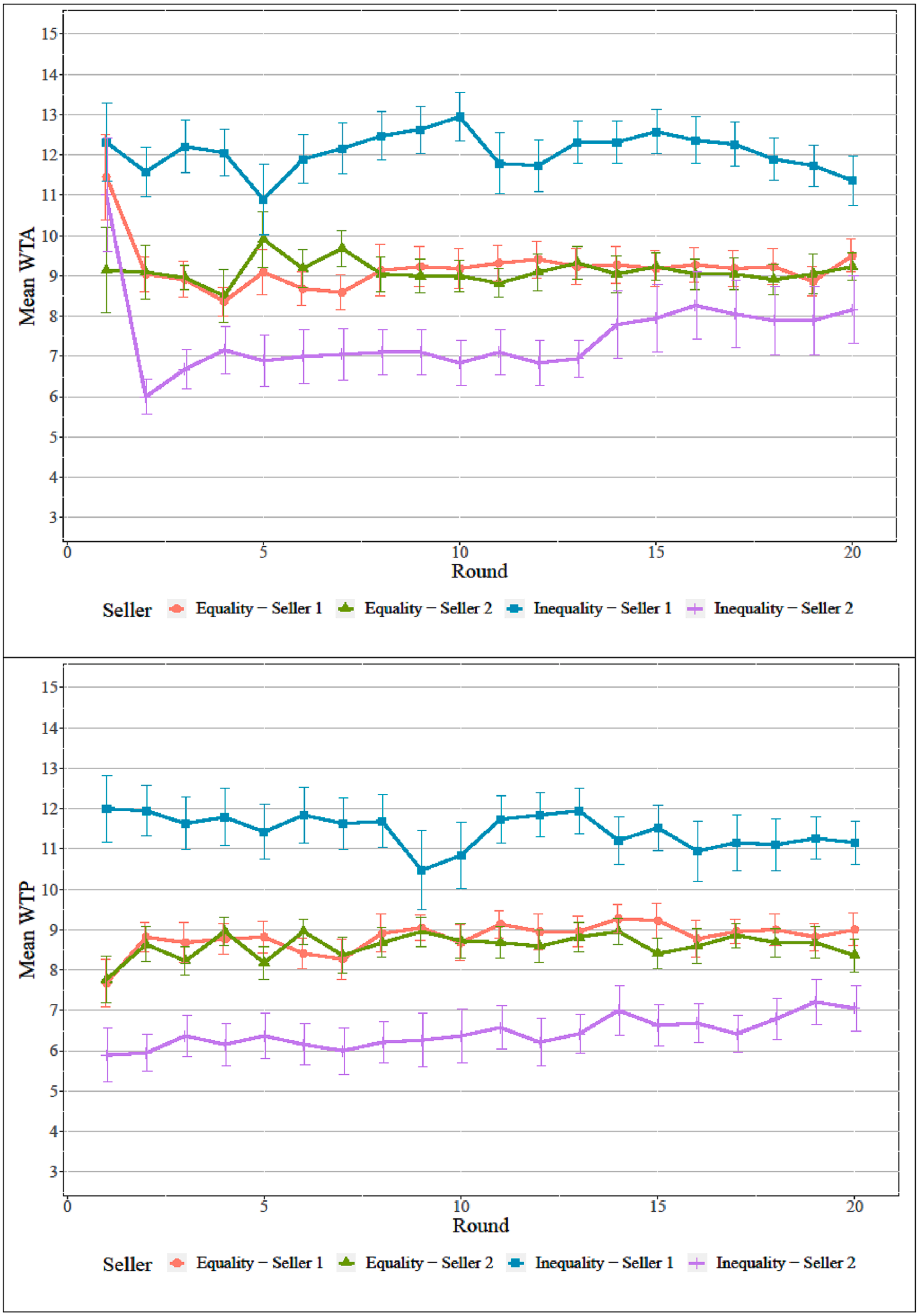

Fig. 3. Study 1 - Mean Willingness to Accept (WTA, top) and Willingness to Pay (WTP, bottom) per Seller Number (1 vs. 2), Treatment (Equality vs. Inequality) and Round Number (1 to 20).

From a formal perspective, the bargaining problem Buyers and Sellers were faced with was exactly the same across conditions.

1.2. Results

Sellers' Asking Prices (WTA). To test whether the (in)equality between the Sellers had an effect on the two Sellers' WTAs, we calculated the WTA difference by subtracting the WTA of Seller 2 (WTA_2) from the WTA of Seller 1 (WTA_1). As a first step, we analyzed Sellers' initial responses, which had not yet been affected by the others' decisions, by testing the effect of Treatment (Equality vs. Inequality) on the WTA difference scores in the first round, only. A non-parametric Mann-Whitney *U* test with continuity correction showed that Treatment did not have a significant effect on the WTA difference scores in the Round 1, $W = 215.5$, $p = .88$. Next, we ran a mixed model regression on the WTA difference scores (as implemented in the lme4 package in R; Bates, Maechler, Bolker, & Walker, 2015),[1] with Treatment (Equality vs. Inequality) and Round Number (1 to 20) as fixed-level predictors, and the group identifier as random intercept. This analysis yielded a significant effect of Treatment, $B = 4.50$, $SE = 0.75$, $t(39) = 6.02$, $p < .001$, indicating that – over all rounds – the difference in WTAs of Seller 1 vs. 2 was larger in the Inequality treatment than in the Equality treatment (see Fig. 2), which is in line with Hypothesis 1. There was no significant effect of Round Number, indicating that the difference between the WTAs of Seller 1 vs. 2 did not become significantly smaller (or larger) over time (see Fig. 3).

Buyers' Willingness to Pay (WTP). To test whether (in)equality also had an effect on the Buyer's WTPs, we calculated the WTP difference by subtracting the WTP for Seller 2 (WTP_2) from the WTP for Seller 1 (WTP_1) in each round. As a first step, we analyzed Buyers' initial responses, by testing the effect of Treatment (Equality vs. Inequality) on the WTP difference scores in Round 1. A Mann-Whitney *U* test with continuity correction showed that Treatment did have a significant effect on the WTP difference scores in the Round 1, $W = 44$, $p < .001$, indicating that the WTP difference score was significantly larger in the Inequality treatment. Next, we fitted a mixed model on the WTP difference score, with Treatment (Equality vs. Inequality) and Round Number (1 to 20) as fixed-level predictors, Buyer's age and gender as individual-level control variables, and the group identifier as random intercept. This analysis again yielded a significant effect of Treatment, $B = 4.82$, $SE = 0.66$, $t(39) = 7.25$, $p < .001$, indicating that – over all rounds – the difference in Buyer's WTPs for Seller 1 vs. 2 was larger in the Inequality treatment than in the Equality treatment (see Fig. 2), which is in line with Hypothesis 2. Hence, mimicking the results of Sellers' WTAs, Buyers were willing to pay more the more puzzle pieces the Seller had in her possession. For Buyers, we also found a significant effect of Round Number, $B = -0.03$, $SE = 0.01$, $t(2416) = -4.45$, $p < .001$, indicating that the difference between the WTPs to Seller 1 vs. 2 became smaller over time. However, it should be noted that the difference in WTPs in the Inequality treatment remained substantial until the very last round (see Fig. 3).

Failure Rates. To test whether the (in)equality between the Sellers also had an effect on the frequency with which the Buyer failed to make a deal with both Sellers, we ran a mixed model logistic regression with failure as a binary dependent variable, Treatment (Equality vs. Inequality) and Round Number (1 to 20) as fixed-level predictors, and the participant and group identifiers as random intercepts. This analysis yielded a significant effect of Treatment, $B = 1.29$, $SE = 0.49$, $z = 2.65$, $p = .008$, and a significant effect of

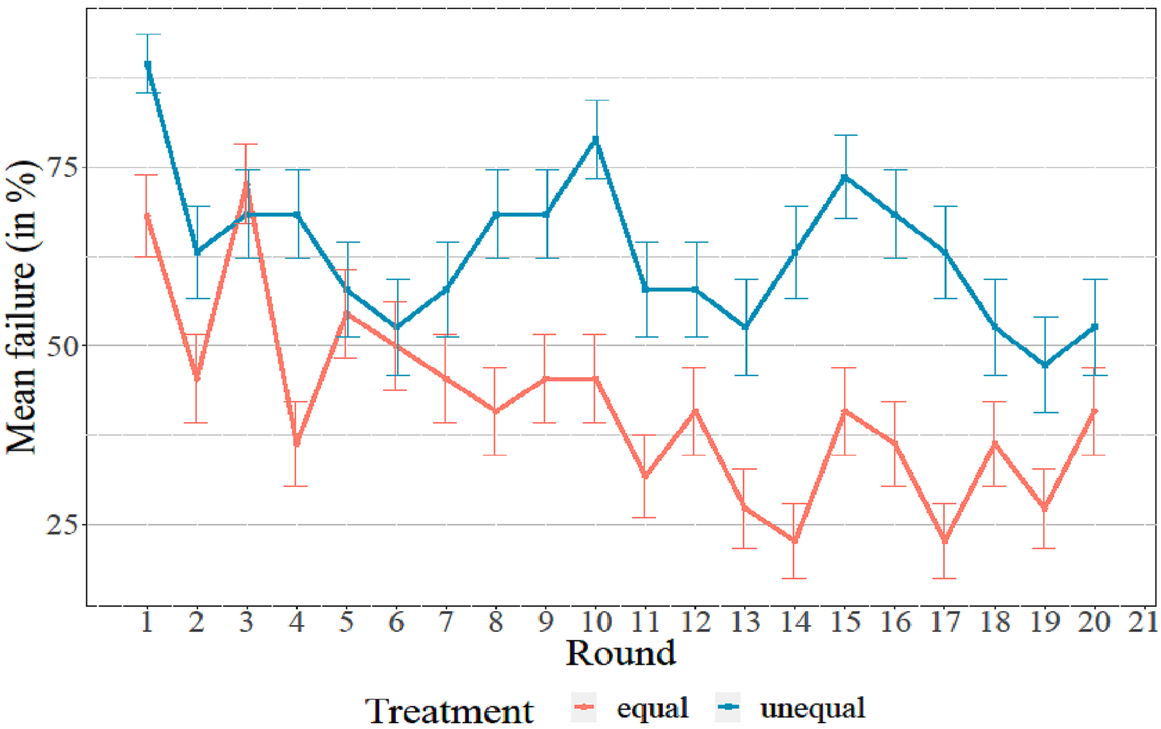

Fig. 4. Study 1 – Mean failure rates per Treatment and Round Number.

Round Number, $B = -0.07$, $SE = 0.01$, $z = -4.77$, $p < .001$. Together, these effects indicated that failure rates were significantly higher in the Inequality treatment ($M = 63.16\%$, $SD = 48.26$) than in the Equality treatment ($M = 41.59\%$, $SD = 49.31$), and that failure rates decreased over time (see Fig. 4). Hence, we observed a more pronounced tragedy of the anticommons (i.e., underuse of resources) under Inequality.

Payoffs. We also analyzed the payoffs of Buyers and Sellers. To test whether (in)equality had an effect on the Buyers' payoffs, we first looked at the Buyers' earnings in the task. Specifically, we ran a mixed model regression with Treatment (Equality vs. Inequality) and Round Number (1 to 20) as fixed-level predictors, the participant and group identifiers as random intercepts, gender and age as individual-level control variables, and the Buyer's payoff (in number of points) as the outcome variable. This analysis showed that Buyers in the Inequality treatment earned significantly fewer points per round than Buyers in the Equality treatment, $B = -3.48$, $SE = 1.09$, $t(37) = -3.19$, $p = .003$ ($M = 15.97$, $SD = 6.55$ vs. $M = 19.29$, $SD = 5.57$), which can be explained by the higher failure rates in the former treatment.

To analyze Sellers' payoffs, we ran a mixed model linear regression with Treatment (Equality vs. Inequality), Seller Number (1 vs. 2) and Round Number (1 to 20) as fixed-level predictors, the participant and group identifiers as random intercepts, age and gender as individual-level control variables, and the Seller's payoffs (in number of points) as the outcome variable. In a second step, we also added the Treatment by Seller Number interaction. These analyses yielded a significant effect of Seller Number, $B = -1.69$, $SE = 0.56$, $t(38.20) = -3.01$, $p = .005$, which indicated that Sellers 1 earned significantly more points per round than Sellers 2. We also found a main effect of Round Number, $B = 0.11$, $SE = 0.02$, $t(1557) = 6.46$, $p < .001$, which indicated that the Sellers' payoffs increased over rounds. Finally, we found a significant Treatment by Seller Number interaction effect, $B = -2.90$, $SE = 1.10$, $t(40.02) = -2.64$, $p = .012$, indicating that the difference in payoffs between the two Sellers was larger in the Inequality condition ($M = 7.27$, $SD = 6.18$ vs. $M = 4.13$, $SD = 3.68$) than in the Equality condition ($M = 6.41$, $SD = 4.11$ vs. $M = 5.98$, $SD = 4.21$).

Exploratory Analyses: Motive Questions. For exploratory reasons, we also analyzed participants' responses to the 8 Likert-scale motive questions that were posed at the end of the group task. Primarily, we looked at whether Seller 1′s responses differed from those of Seller 2, and whether this difference was larger in the Inequality treatment, which might imply that such divergence in self-reported motives played a role in the Treatment effects we found for their WTAs. Specifically, we separately analyzed each motive with a mixed model (with Bonferroni-correction for the number of tests: $p < .006$), with Treatment and Seller Number and the Treatment by Seller Number interaction as fixed-level predictors, the group identifier as a random intercept, and gender and age as individual-level control variables. These exploratory analyses indicated that, in the Inequality treatment (as compared to Equality), Sellers 1 (as compared to Sellers 2) felt entitled to earn more points than the others, $B = 2.29$, $SE = 0.70$, $t(78.47) = 3.27$, $p = .002$, whereas Sellers 2 (as compared to Sellers 1) felt that they deserved less points than the others, $B = -2.03$, $SE = 0.70$, $t(115) = -2.89$, $p = .005$.

1.3. Discussion

The results of Study 1 provided first support for the use of a more-is-better heuristic in bargaining for complementary resources, in which quantity is actually not part of the objective payoff contingencies. That is, Sellers with many resources demanded more money than Sellers with few resources, and Buyers also offered more money to Sellers with many resources. As a result, in the Equality treatment – in which both Sellers had an equal amount of resources – the difference between the asking prices of the two Sellers was significantly smaller than in the Inequality treatment. Similarly, the difference between offers to the two Sellers was also larger in the Inequality condition (as compared to Equality). Interestingly, however, our analyses indicated that initially the 'more-is-better' bias was stronger in Buyers than in Sellers, as in Round 1 – when participants had not yet been affected by the others' decisions – only the effect of Treatment on the WTP difference scores was significant (and not the effect on the WTA difference scores). Additionally, we observed that although the failure rate decreased over rounds (indicative of a group learning effect), the difference between Seller 1 and 2 – in terms of WTA, WTP and payoffs – remained until the very last round. Finally, the data also showed that failure rates were higher in the Inequality treatment than in the Equality treatment, suggesting that it was more difficult for Sellers and Buyers to co-ordinate their decisions under inequality (cf. De Kwaadsteniet & Van Dijk, 2012; Van Dijk, Wit, Wilke, & De Kwaadsteniet, 2010). Hence, inequality increased the severity of the anticommons dilemma. Our results reveal how irrelevant characteristics of the bargaining environment (in our case the quantity of owned resources) can impede efficient trades and result in underuse of the commons when traders focus more on the quantity than on the complementarity of the resources they own.

2. Study 2

The results of Study 1 corroborate the idea that both Sellers and Buyers treat complementary resources as if they are non-complementary (Alvisi & Carbonara, 2013), and base their decisions on a more-is-better heuristic. In Study 2, we explored a possible boundary condition of this effect. That is, we asked ourselves under which circumstances Buyers and Sellers might start to realize that both Sellers are equally pivotal, and thus that the pieces of both Sellers should be equally valuable to the Buyer. In other words, what would make them more aware of the complementarity of the different parts and realize that it should not matter whether a Seller owns few or many pieces, thereby curbing the tragedy of the anticommons?

Although seemingly paradoxical at first, we reasoned that making the inequality between the Sellers more extreme might make traders more aware that the inequality between Sellers is not the most relevant issue to focus on, but rather that both Sellers' resources are equally pivotal. For instance, imagine that one of the Sellers would only own 1 piece of a 100-piece puzzle, whereas the other would own all other 99 puzzle pieces. How would such extreme inequality affect their perception and valuation of both parts? We know from psychological research that goods that are unique draw attention (see e.g., Jeck, Qin, Egeth & Niebur, 2019), and that people may value scarce resources more than resources that are abundant (see e.g., John, Melis, Read, Rossano & Tomasello, 2018). In other words, resources that are perceived as relatively scarce and unique – for instance, 1 specific piece of a 100-piece puzzle – tend to attract more attention and are valued more than their less unique and more abundant counterparts. The increased attention for this single puzzle piece – and the extra value that people put on scarce resources – might make both Sellers and Buyers realize that this single piece is also pivotal for the task at hand, and make them more aware of the complementarity involved (cf. Dhont et al, 2012). This awareness of complementarity could, in turn, reduce bargainers' use of a "more-is-better" heuristic found in Study 1.

To test this possibility, we used the same Anticommons Bargaining Game as in Study 1. However, this time we used a 100-piece puzzle of which Seller 1 initially owned 99 pieces, whereas Seller 2 owned only 1 piece. The payoff contingencies and rules of the task remained exactly the same. Based on the above reasoning, this second study was thus conducted to see whether we would replicate the findings of Study 1 in the Anticommons Bargaining Game with more extreme inequality or whether this effect might actually become smaller or disappear completely under such extreme inequality.

2.1. Method

Participants and Design. We recruited 120 participants for a study about "social decision making" (23 males, 97 females, $M_{\text{age}} = 19.63$, $SD_{\text{age}} = 2.26$). For their participation in this study, which took approximately 15 to 20 min to complete, they received 2 euros (or 1 course credit) plus the amount of money they earned in the Anticommons Bargaining Game. Just as Study 1, this study had a between-subjects design with 2 treatments (Equality vs. Inequality).

Procedure. The procedure of this study was almost identical to the procedure of Study 1. Again, participants were assigned to three-person groups and were presented with a 20-round Anticommons Bargaining Game, which was called "puzzle-pieces task". The only difference between the studies was that this time the puzzle in the Anticommons Bargaining Game consisted of 100 pieces (instead of 4), and that in the Inequality condition the inequality was much larger than in the Study 1. That is, in the Equality condition each Seller started each round with 50 puzzle pieces (see Fig. 5). In the Inequality condition, by contrast, Seller 1 started each round with 99 puzzle pieces, whereas Seller 2 started with 1 puzzle piece (see Fig. 5). Importantly, the payoff structure of the puzzle-pieces task was exactly the same as in Study 1.

2.2. Results

Sellers' Asking Prices (WTA). As a first step, we analyzed Sellers' initial responses, by testing the effect of Treatment (Equality vs. Inequality) on the WTA difference scores in Round 1. A Mann-Whitney *U* test with continuity correction showed that Treatment did not have a significant effect on the WTA difference scores in Round 1, $W = 134.3$, $p = .078$ (similar to Study 1). Next, we ran a mixed model regression on the WTA difference scores, with Treatment (Equality vs. Inequality) and Round Number (1 to 20) as fixed-level predictors, and the group identifier as random intercept. This analysis yielded a significant effect of Treatment, $B = 4.46$, $SE = 0.82$, $t(38) = 5.41$, $p <. 001$, indicating that – over all rounds – the difference in WTAs of Seller 1 vs. 2 was larger in the Inequality treatment than in the Equality treatment (see Fig. 6), which is in line with our original Hypothesis 1 (see Study 1). Moreover, there was a significant effect of Round Number, $B = -0.07$, $SE = 0.01$, $t(2359) = -6.80$, $p < .001$, indicating that the difference between the WTAs of Seller 1 vs.

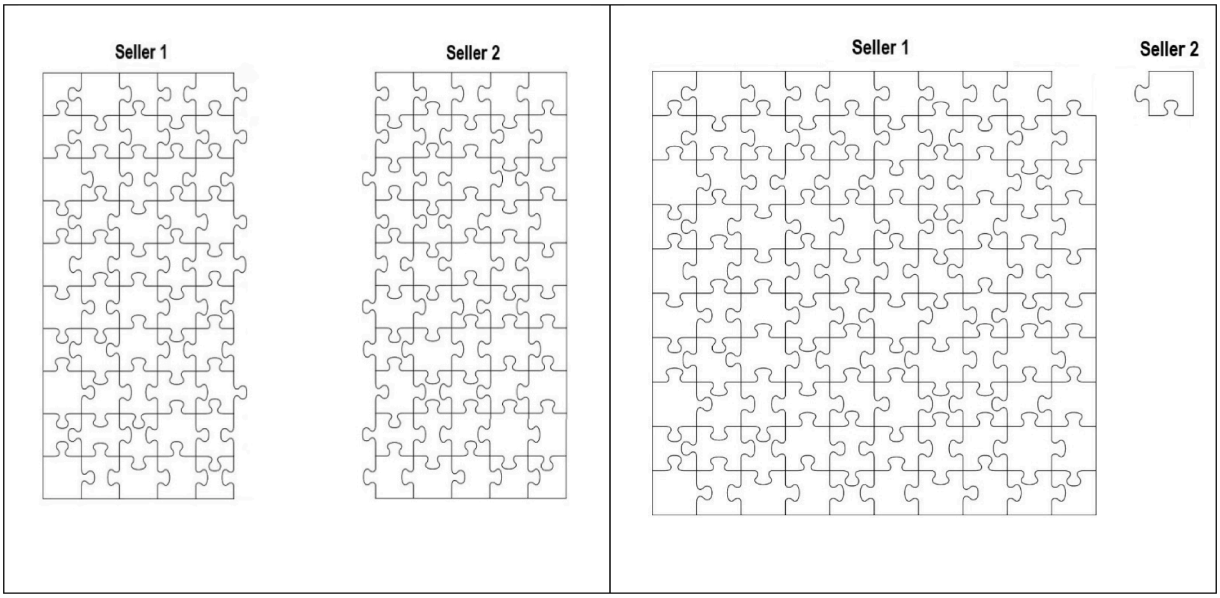

Fig. 5. Study 2 – Graphical Representations of the Puzzle Pieces in the Equality (left) vs. Inequality Condition (right).

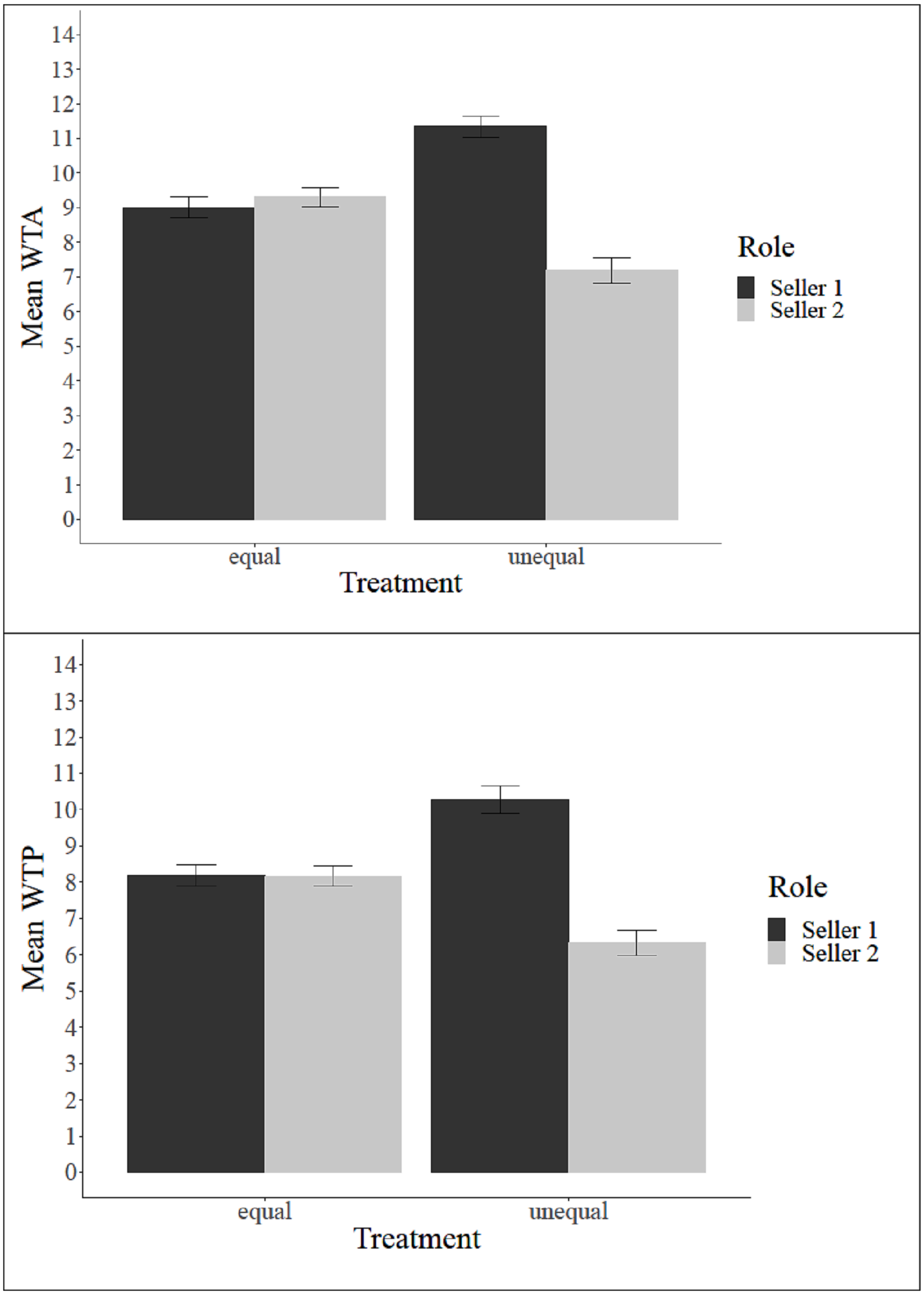

Fig. 6. Study 2 - Mean Willingness to Accept (WTA, top) and Willingness to Pay (WTP, bottom) per Seller Number (1 vs. 2) and Treatment (Equality vs. Inequality).

2 became smaller over time (see Fig. 7).

Buyers' Willingness to Pay (WTP). As a first step, we analyzed Buyers' initial responses, by testing the effect of Treatment (Equality vs. Inequality) on the WTP difference scores in Round 1. A Mann-Whitney *U* test with continuity correction showed that Treatment did have a significant effect on the WTA difference scores in Round 1, $W = 94$, $p = .001$, indicating that the WTP difference score was significantly larger in the Inequality treatment (again, similar to Study 1). Next, we ran a mixed model regression on Buyers' WTP difference scores, with Treatment (Equality vs. Inequality) and Round Number (1 to 20) as fixed-level predictors, age and gender as individual-level control variables, and the group identifier as random intercept. This analysis, like in Study 1, yielded a significant effect of Treatment, $B = 3.94$, $SE = 0.79$, $t(37.88) = 4.98$, $p < .001$, indicating that – over all rounds – the difference in WTPs to Seller 1 vs. 2 was larger in the Inequality treatment than in the Equality treatment (see Fig. 6), which is in line with our original Hypothesis 2. Moreover, we also found a significant effect of Round Number, $B = -0.04$, $SE = 0.01$, $t(2357) = -4.95$, $p < .001$, indicating that the

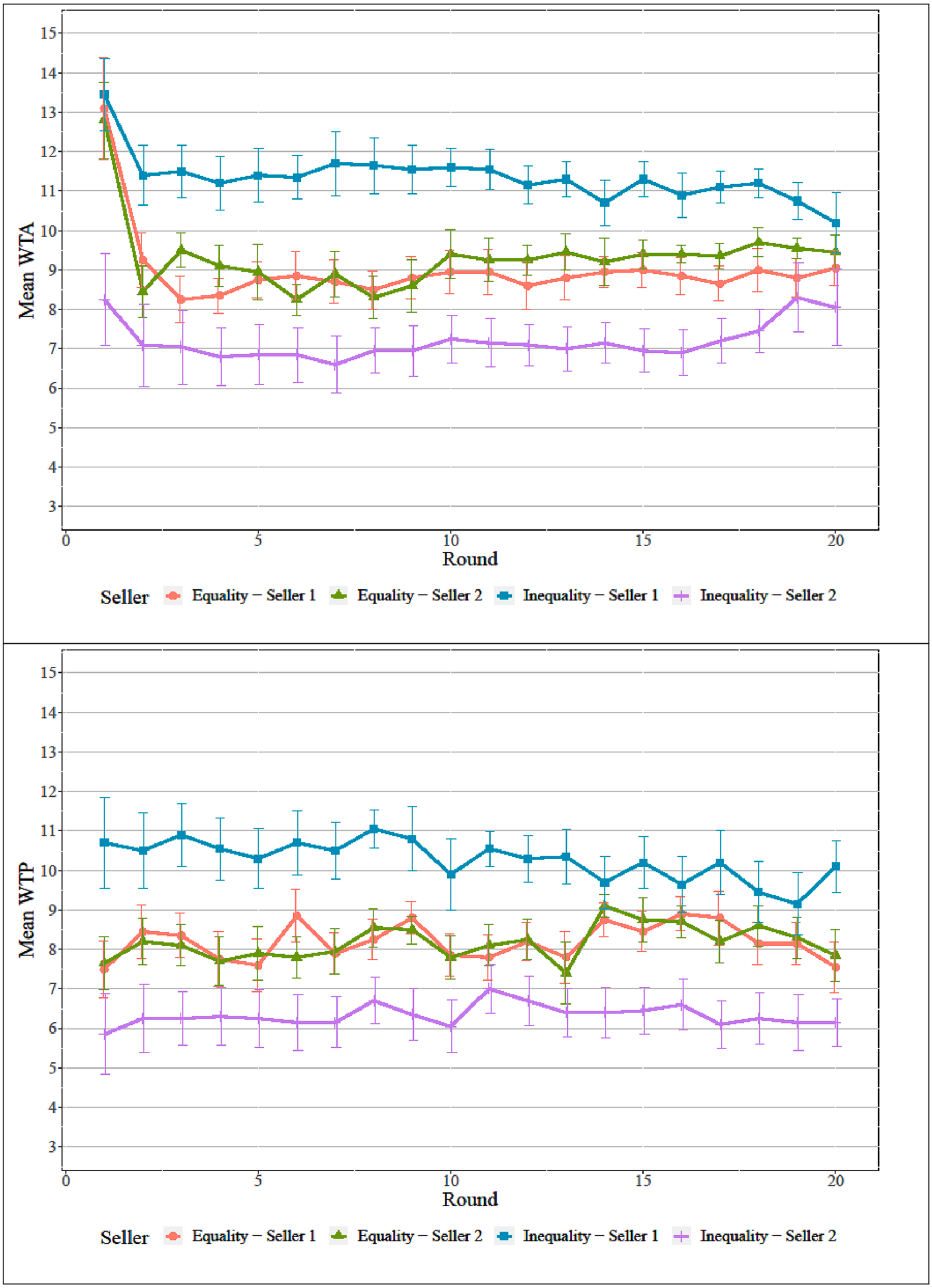

Fig. 7. Study 2 - Mean Willingness to Accept (WTA, top) and Willingness to Pay (WTP, bottom) per Seller Number (1 vs. 2), Treatment (Equality vs. Inequality) and Round Number (1 to 20).

difference between the WTPs to Seller 1 vs. 2 became smaller over time (see Fig. 7).

Failure Rates. To test whether the (in)equality between the Sellers also had an effect on the frequency with which the Buyer failed to make a deal with both Sellers, and thus failed to obtain the whole puzzle, we ran mixed model logistic regressions. First, we ran a model with Treatment (Equality vs. Inequality) and Round Number (1 to 20) as fixed-level predictors, the participant and group identifiers as random intercepts, and the Failure Rates as the outcome variable. These analyses only yielded a significant main effect of Round Number, $B = -0.04$, $SE = 0.01$, $z = -3.142$, $p = .002$, indicating that failure rates decreased over time (see Fig. 8).

Payoffs. To test whether the (in)equality had an effect on the Buyers' payoffs, we again ran mixed model regressions. We ran a model with Treatment (Equality vs. Inequality) and Round Number (1 to 20) as fixed-level predictors, the participant and group identifiers as random intercepts, gender and age as individual-level control variables, and the Buyer's payoff (in number of points) as the outcome variable. This analysis showed no significant effects of the Treatment or Round Number on the Buyer's payoff (both $ps > 0.114$).

Next, we also ran mixed model linear regressions on the Sellers' payoffs. First, we ran a model with Treatment (Equality vs. Inequality), Seller Number (1 vs. 2) and Round Number (1 to 20) as fixed-level predictors, the participant and group identifiers as random intercepts, gender and age as individual-level control variables, and the Seller's payoffs (in number of points) as the outcome variable. Second, we added the Treatment by Seller Number interaction. These analyses yielded a significant main effect of Seller Number, $B = -1.53$, $SE = 0.49$, $t(36.72) = -3.13$, $p = .003$, and a significant main effect of Round Number, $B = 0.06$, $SE = 0.02$, $t(1519.00) = 3.49$, $p < .001$. Moreover, as in Study 1, we also found a significant Treatment by Seller Number interaction effect, $B = -3.06$, $SE = 0.86$, $t(35.76) = -3.58$, $p = .001$. In line with the results of Study 1, this interaction indicated that the difference in payoffs of Seller 1 vs. 2 was larger in the Inequality treatment ($M = 7.23$, $SD = 5.38$ vs. $M = 4.17$, $SD = 3.83$) than in the Equality treatment ($M = 4.73$, $SD = 4.33$ vs. $M = 4.79$, $SD = 4.43$).

Exploratory Analyses: Motive Questions. As in Study 1, we also explored participants' responses to the 8 Likert-scale motive questions that were posed at the end of the group task. Specifically, we looked at whether Seller 1′s responses differed from those of Seller 2, and whether this difference was larger in the Inequality treatment. We did this by fitting separate mixed models for each motive (with Bonferroni-correction for the number of tests: $p < .006$), with Treatment and Seller Number and the Treatment by Seller Number interaction as fixed-level predictors, the group identifier as a random intercept, and gender and age as control variables. These exploratory analyses indicated that there were no significant differences on these motive questions between the Sellers 1 and 2 (all $ps > 0.070$).

2.3. Discussion

The results of Study 2 again provide support for the more-is-better hypothesis, but this time in an Anticommons Bargaining Game with more extreme inequality. Just as in Study 1, Sellers with more resources demanded more money than Sellers with less resources,

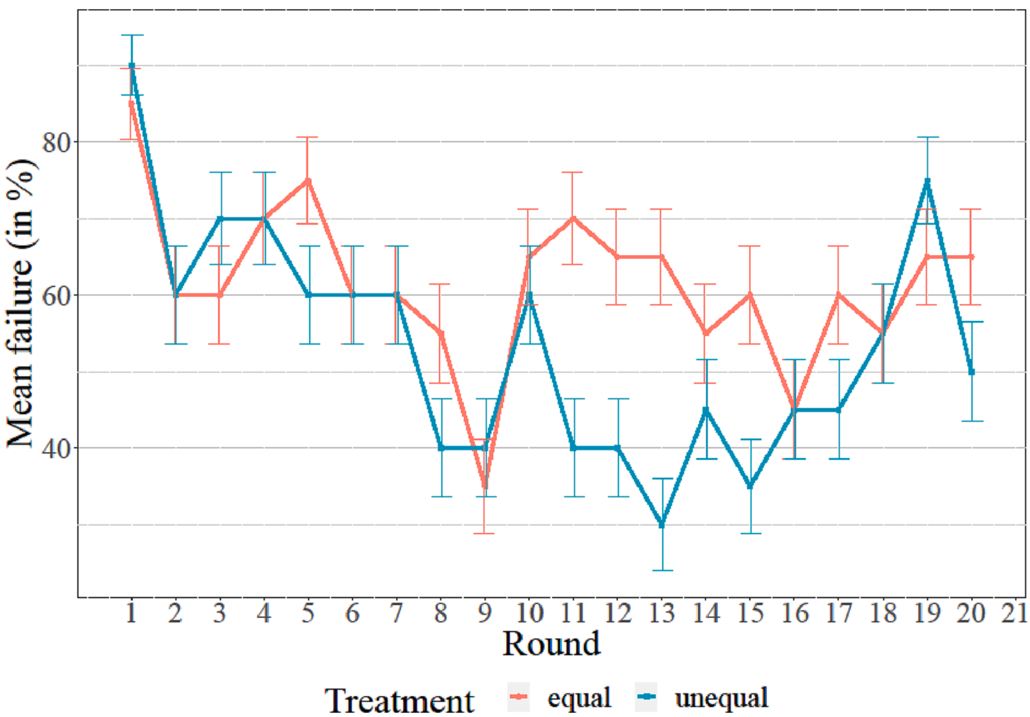

Fig. 8. Study 2 – Mean Failure Rates per Treatment and Round Number.

and Buyers also offered more money to Sellers with more resources. As a result, the difference between the WTAs of Seller 1 vs. 2 was significantly larger in the Inequality condition than in the Equality condition. Likewise, the difference of Buyers' WTPs to Seller 1 vs. 2 was significantly larger under Inequality as well. Furthermore, our analyses again indicated that initially the 'more-is-better' bias was stronger in Buyers than in Sellers, as in Round 1 only the effect of Treatment on the WTP difference scores was significant. The findings of Study 2 were thus highly similar to those of Study 1, and in line with hypotheses 1 and 2. However, it should be noted that, in contrast to Study 1, in Study 2 we did not find any significant differences in failure rates and payoffs between the Equality and Inequality treatments (we will address this finding in the general discussion in more detail).

That the findings of Study 1 and 2 were so similar (especially regarding WTA and WTP) can possibly be explained by the fact that in both studies we compared a perfectly equal condition with an unequal condition. A remaining open question therefore is whether the effect is due to the distinction between perfect equality vs. inequality, or whether the effect would also occur when we compare more moderate degrees of inequality with one another. Our third Study was specifically designed to test this.

3. Study 3

Based on the above reasoning, we designed our third study, in which we compared two different degrees of inequality with one another (i.e., small inequality vs. large inequality). By varying the degree of inequality, we can test whether the more-is-better effect is either driven by the distinction between perfect equality vs. inequality (Study 1 and 2) or by the degree of the inequality (Study 3). If the more-is-better effect is primarily driven by the distinction between perfect equality vs. inequality, then it should not be affected much by the degree of inequality between the two Sellers. By contrast, if the degree of inequality is the main driver of the more-is-better effect, then the more-is-better effect should become larger when the degree of inequality between the Sellers is larger.

3.1. Method

Participants and Design. We recruited 123 participants for a study about "social decision making" (17 males, 103 females, 3 preferred to self-identify, $M_{\text{age}} = 21.28$, $SD_{\text{age}} = 3.50$). For their participation in this study, which took approximately 15 to 20 min to complete, they received 2 euros (or 1 course credit) plus the amount of money they earned in the Anticommons Bargaining Game. The study had a between-subjects design with 2 treatments (Small Inequality vs. Large Inequality).

Procedure. The procedure of this study was almost identical to the procedure of Studies 1 and 2. As in Study 2, we again presented participants with a 100-piece puzzle. However, this time groups were randomly assigned to either a Small Inequality or a Large Inequality treatment. In the Small Inequality condition Seller 1 started each round with 59 puzzle pieces, whereas Seller 2 started with 41 puzzle piece (see Fig. 9). In the Large Inequality condition, Seller 1 started each round with 90 puzzle pieces, whereas Seller 2 started with 10 puzzle pieces (see Fig. 9). Importantly, the payoff structure of the puzzle-pieces task was exactly the same as in Studies 1 and 2.

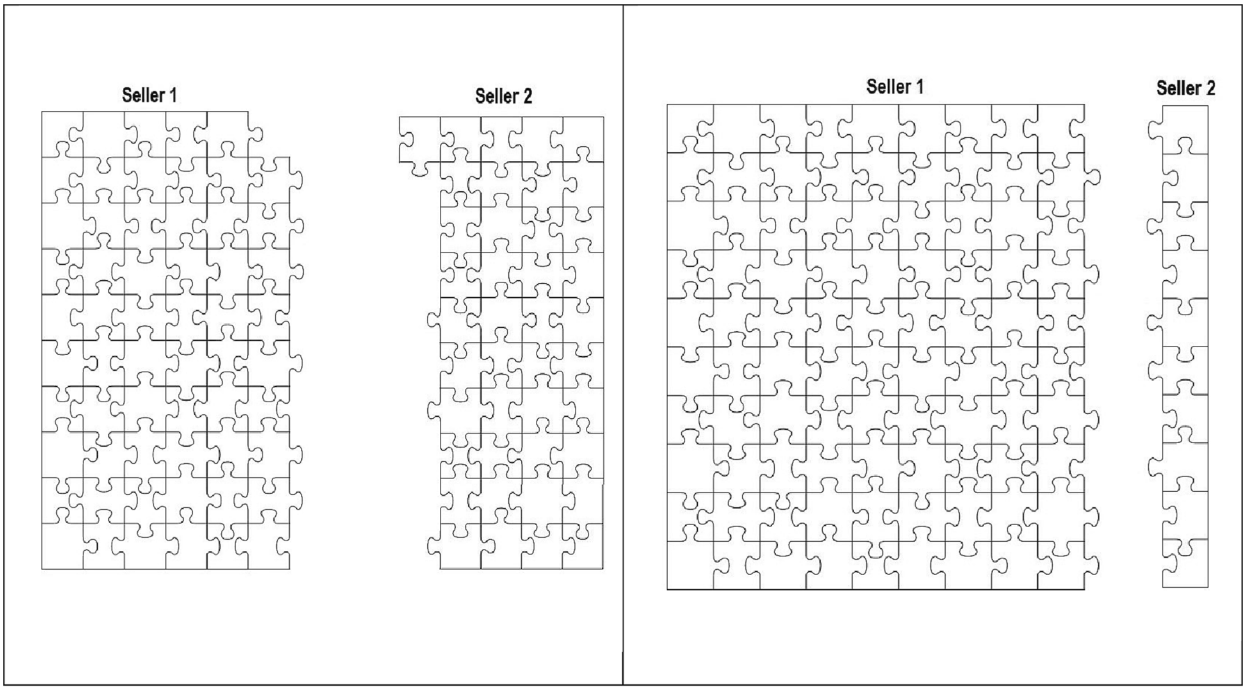

Fig. 9. Study 3 – Graphical Representations of the Puzzle Pieces in the Small (left) vs. Large Inequality Treatment (right).

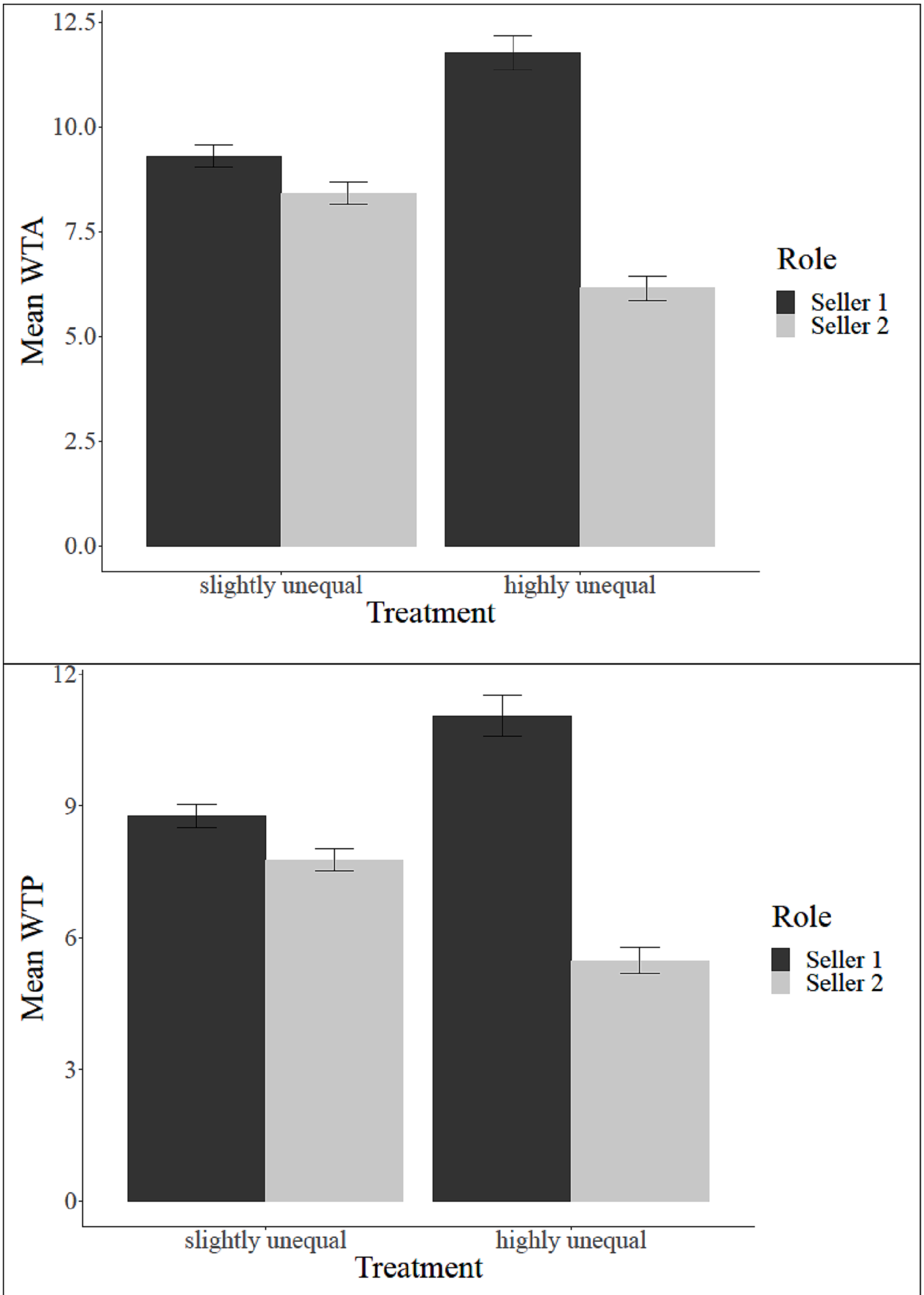

Fig. 10. Study 3 - Mean Willingness to Accept (WTA, top) and Willingness to Pay (WTP, bottom) per Seller Number (1 vs. 2) and Treatment (Small Inequality vs. Large Inequality).

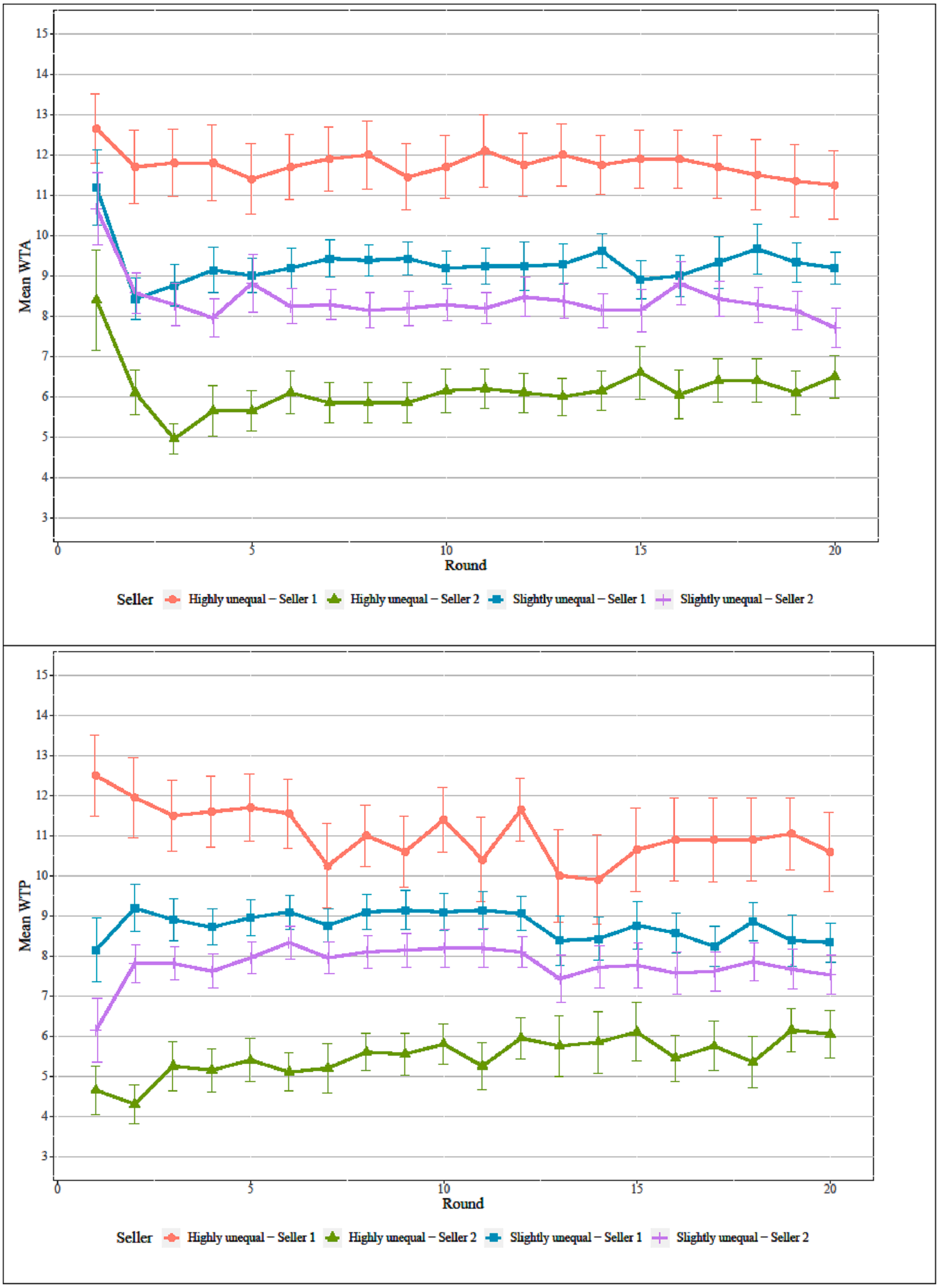

Fig. 11. Study 3 - Mean Willingness to Accept (WTA, top) and Willingness to Pay (WTP, bottom) per Seller Number (1 vs. 2), Treatment (Small Inequality vs. Large Inequality) and Round Number (1 to 20).

3.2. Results

Sellers' Asking Prices (WTA). As a first step, we analyzed Sellers' initial responses, by testing the effect of Treatment (Equality vs. Inequality) on the WTA difference scores in Round 1, only. A Mann-Whitney *U* test with continuity correction showed that Treatment did not have a significant effect on the WTA difference scores in Round 1, $W = 137$, $p = .058$. Next, we ran a mixed model regression on the WTA difference scores, with Treatment (Small Inequality vs. Large Inequality) and Round Number (1 to 20) as fixed-level predictors, and the group identifier as random intercept. This analysis yielded a significant effect of Treatment, $B = 4.72$, $SE = 1.06$, $t(39) = 4.45$, $p < .001$, indicating that – over all rounds – the difference in WTAs of Seller 1 vs. 2 was larger in the Large Inequality treatment than in the Small Inequality treatment (see Fig. 10), which is again in line with our original Hypothesis 1.

Buyers' Willingness to Pay (WTP). As a first step, we analyzed Buyers' initial responses, by testing the effect of Treatment (Equality vs. Inequality) on the WTP difference scores in Round 1. A Mann-Whitney *U* test with continuity correction showed that Treatment did have a significant effect on the WTA difference scores in the Round 1, $W = 74.5$, $p < .001$, indicating that the WTP difference score was significantly larger in the Inequality treatment. Next, we ran a mixed model regression on the WTP difference scores, with Treatment (Small Inequality vs. Large Inequality) and Round Number (1 to 20) as fixed-level predictors, age and gender as individual-level control variables, and the group identifier as random intercept. This analysis again yielded a significant effect of Treatment, $B = 4.58$, $SE = 1.01$, $t(39.02) = 4.54$, $p < .001$, indicating that – over all rounds – the difference in Buyers' WTP for Seller 1 vs. 2 was larger in the Large Inequality treatment than in the Small Inequality treatment (see Fig. 10), which is in line with our original Hypothesis 2. Moreover, we also found a significant effect of Round Number, $B = -0.08$, $SE = 0.01$, $t(2415) = -10.74$, $p < .001$, indicating that the difference between the WTPs to Seller 1 vs. 2 became smaller over time (see Fig. 11).

Failure Rates. To test whether the degree of inequality between the Sellers also had an effect on the frequency with which the Buyer failed to make a deal with both Sellers, we again ran mixed model logistic regressions. We ran a model with the Treatment (Small Inequality vs. Large Inequality) and Round Number (1 to 20) as fixed-level predictors, the participant and group identifiers as random intercepts, and the Failure Rates as the outcome variable. These analyses yielded a significant effect of Round Number, $B = -0.08$, $SE = 0.01$, $z = -5.41$, $p < .001$. Similar to Studies 1 and 2, this effect indicated that failure rates decreased over time (see Fig. 12).

Payoffs. To test whether the (in)equality had an effect on the Buyers' payoffs, we again ran mixed model regressions. We ran a model with Treatment (Small Inequality vs. Large Inequality) and Round Number (1 to 20) as fixed-level predictors, the participant and group identifiers as random intercepts, gender and age as individual-level control variables, and the Buyer's payoff (in number of points) as the outcome variable. This model only yielded a significant main effect of Round Number, $B = 0.10$, $SE = 0.03$, $t(778) = 3.14$, $p = .002$, indicating that Buyers' payoffs increased over time.

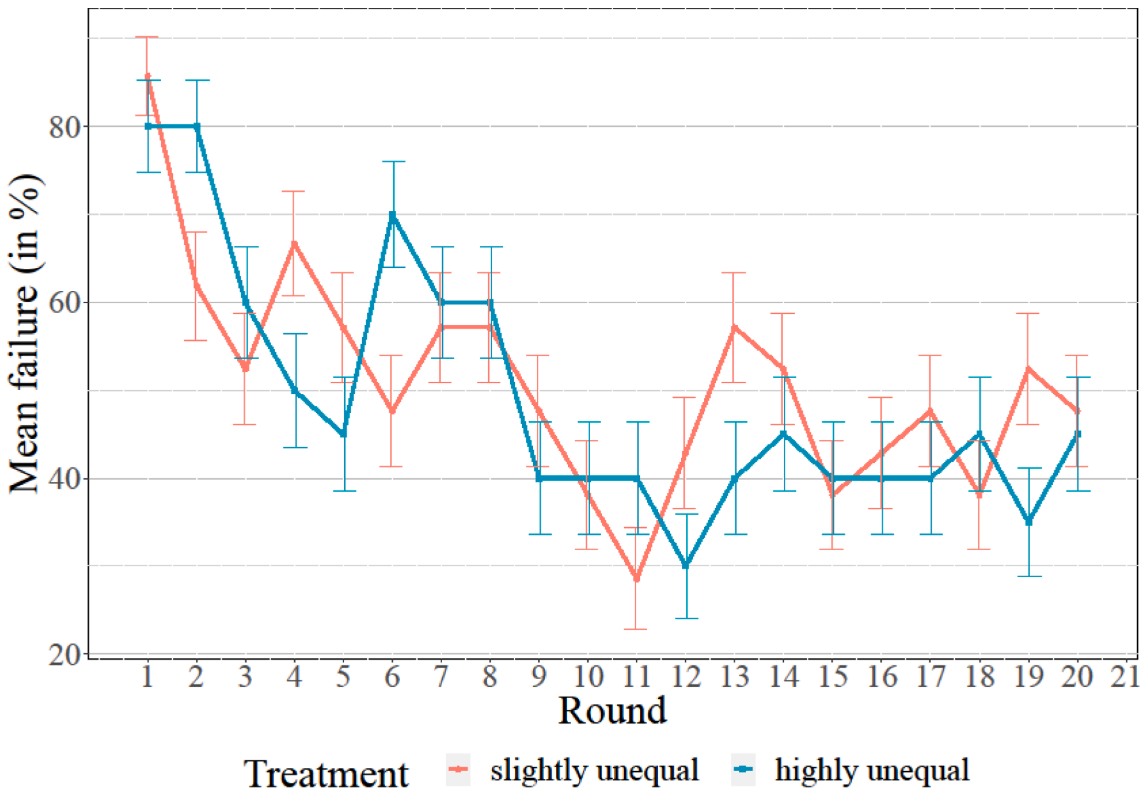

Fig. 12. Study 3 - Mean Failure Rates per Treatment and Round Number.

Next, we also ran mixed model linear regressions on the Sellers' payoffs. First, we ran a model with Treatment (Small Inequality vs. Large Inequality), Seller Number (1 vs. 2) and Round Number (1 to 20) as fixed-level predictors, the participant and group identifiers as random intercepts, gender and age as individual-level control variables, and the Seller's payoffs (in number of points) as the outcome variable. Second, we added the Treatment by Seller Number interaction. These analyses yielded a significant main effect of Seller Number, $B = -2.55$, $SE = 0.60$, $t(39.74) = -4.23$, $p < .001$, indicating that Sellers 1 earned more than Sellers 2, and a significant main effect of Round Number, $B = 0.10$, $SE = 0.02$, $t(1557) = 6.14$, $p < .001$, indicating that Sellers' payoffs increased over time. Moreover, we again found a significant Treatment by Seller Number interaction effect, $B = -4.08$, $SE = 0.98$, $t(36.87) = -4.15$, $p < .001$, indicating that the difference in payoffs of Seller 1 vs. 2 was larger in the Large Inequality treatment ($M = 8.15$, $SD = 6.08$ vs. $M = 3.64$, $SD = 3.25$) than in the Small Inequality treatment ($M = 5.83$, $SD = 4.54$ vs. $M = 5.22$, $SD = 4.11$).

Exploratory Analyses: Motive Questions. As in Studies 1 and 2, we again explored participants' responses to the 8 Likert-scale motive questions that were posed at the end of the group task. Specifically, we looked at whether Seller 1′s responses differed from those of Seller 2, and whether this difference was larger in the Inequality treatment. We did this by fitting 8 separate mixed models (with Bonferroni-correction for the number of tests: $p < .006$), with Treatment and Seller Number and the Treatment by Seller Number interaction as fixed-level predictors, the group identifier as a random intercept, and gender and age as individual-level control variables. As in Study 2, these exploratory analyses indicated that there were no significant differences on these motive questions between the two Sellers (all $ps > 0.051$).

3.3. Discussion

The results of Study 3 again provided support for a more-is-better heuristic, and demonstrate that the strength of its influence is dependent on the degree of inequality, as if quantity would (linearly) reflect value. Just as in Studies 1 and 2, Sellers with more resources demanded more money than Sellers with less resources, and Buyers also offered more money to Sellers with more resources. Furthermore, this difference was significantly larger under large inequality than under small inequality. In line with Studies 1 and 2, our analyses also indicated that initially the 'more-is-better' bias was stronger in Buyers than in Sellers, as in Round 1 only the effect of Treatment on the WTP difference scores was significant. The findings of Study 3 were thus highly similar to those of Studies 1 and 2, even though we did not have a perfectly equal condition in this case. In other words, the influence of the more-is-better heuristic is dependent on the degree of inequality (and, thus, differences in quantity), and is not only observed when we compare perfect equality with inequality.

4. General discussion

The current paper tested how people make decisions in anticommons situations, situations characterized by fragmented ownership of complementary resources. In three experimental studies, we found support for the idea that people often treat complementary resources as if they are non-complementary (cf. Alvisi & Carbonara, 2013), and that they then fall back on heuristics that should – at least from an economic perspective – only be relevant in the case of non-complementary resources. Specifically, with our newly developed Anticommons Bargaining Game, we showed that owners of perfectly complementary resources as well as the potential Buyers of such resources used a more-is-better heuristic when determining their prices. That is, Sellers who owned a larger part of the puzzle asked a higher price for their resources than Sellers with a smaller part. Likewise, Buyers offered more money to Sellers with a larger part than to Sellers with a smaller part. Applying such a more-is-better valuation makes perfect sense in the case of non-complementary resources, in which case more of the resource actually increases overall value (e.g., in the case of land, bread or water). Yet, quantity should be irrelevant when the resources are perfectly complementary to one another (as in our Anticommons Bargaining Game).

Our results thus corroborate the idea that people tend to treat complementary resources as if they are non-complementary (cf. Alvisi & Carbonara, 2013). A next question then is whether this treatment of complementary resources as non-complementary might provide an explanation of why anticommons situations tend to result in collective underuse (Heller, 1998; 2008). Specifically, does the use of a more-is-better logic lead to coordination problems between Sellers and Buyers and a higher prevalence of anticommons tragedies, especially when complementary resources are unequally distributed from the start? In the present paper, we only found partial support for this idea. That is, only in Study 1 we found that – under (large) inequality – Sellers and Buyers failed more often in making deals (as compared to equality or small inequality). However, when we look at both Sellers and Buyers price-setting strategies, it appears that they – to some degree – agreed or coordinated on a 'more-is-better' heuristic. As a result, even under large inequality, Sellers and Buyers were able to coordinate their prices quite efficiently, especially in later rounds. So, although at first glance the use of a more-is-better heuristic appears to be illogical in the case of perfectly complementary resources, this does not necessarily mean that it hampers coordination or decreases collective payoffs. The use of the more-is-better valuation, however, led to large payoff inequalities between the Seller with the large part and the Seller with the small part.

Although both Sellers and Buyers applied a more-is-better valuation, it should be noted that our analyses of the initial first-round responses – when their pricing decisions had not yet been influenced by the others – indicated that Buyers showed a stronger individual "more-is-better" bias than Sellers did. After all, in the first round, Inequality only had a significant effect on the WTP difference scores, but not on the WTA difference scores. When taking a closer look at the responses of the Sellers (especially Sellers 2 in the Inequality treatment) it appears that they tended to initially ask a relatively high price for their part of the puzzle (i.e., higher than the Buyer was willing to pay), after which they adjusted their prices downward. In other words, in the first round, these Sellers may have tried to earn more points by setting high asking prices, after which they might have strategically adjusted to the Buyers' relatively low first round offers, in order to prevent further coordination failures. As such, we cannot rule out the possibility that strategic concerns (in addition to individual biases) may have partly shaped the Sellers' pricing decisions (see also Achtypi, Ashby, Brown, Walasek, & Yechiam, 2021). Strategic concerns may be especially influential in partner matching protocols, such as the one we used in the present paper. After all, in our Anticommons Bargaining Game the group composition remained the same until the end of the game, with full behavioral information in between rounds. Additionally, we decided to pay participants for all rounds – instead of randomly selecting one round for payment – which might have caused (potentially individual-specific) endowment effects. Despite these limitations, however, the use of this partner matching and payment procedure allowed us to study how groups learn from experience. In future research, the role of strategic and reputational concerns could be ruled out (or at least minimized) by using random partner matching, strategy methods, or a dictator game setting in which only one party is dictating prices.

Another point worth noting is that the asking prices set by the Sellers seemed quite high. This regularly led to deals not being made, which might explain why even in the last rounds of the Equality treatment failure rates were still quite substantial (>40%). Moreover, Buyers often earned significantly less than their starting amount of 20 points. As such, one might wonder whether the participants did not fully understand the group task. However, this seems unlikely, as participants were only allowed to proceed to the game if they had answered all comprehension check questions correctly. Another possible explanation as to why Buyers were willing to "sacrifice" some of their earnings for the benefit of the Sellers might be prosocial motivation. As we know from numerous studies on ultimatum and dictator games (Engel, 2011), people are often willing to share their endowments with others, even if the other has no say over the final distribution. Relatedly, responders in ultimatum game often do not accept offers of less than half of the proposer's starting amount. Looking at our Anticommons Bargaining game, the initial distribution of points between Buyers and Sellers was highly unequal. Whereas the Buyer started the game with 20 points, the two Sellers started with zero points. As such, it might have only seemed fair to them if the Buyers would end up with (substantially) less than this starting endowment, while the Sellers would end up with (substantially) more than zero. In future research, the role of such prosocial motives on anticommons dilemmas could be investigated, for instance, by testing the influence of social value orientation (Murphy & Ackermann, 2014; Van Lange, 1999) on pricing decisions of complementary resources.

At this point, it might be insightful to link our research to a different, but related domain, namely, the field of coalition formation. Coalition formation can be defined as any situation in which two or more individuals or parties need to combine their individual resources in order to realize a collective payoff (Gamson, 1964; Van Beest & Van Dijk, 2007; Wissink, Van Beest, Pronk, & Van de Ven, 2022). For example, political parties can form coalitions to together obtain a majority of seats in parliament. In line with our findings, research on coalition formation has repeatedly shown that people with more resources (often termed "strong" players) tend to demand a larger part of the collective payoff than people with less resources (called "weak" players). For example, the party that has the majority of seats in a winning coalition might demand more ministerial posts. Similar to our studies, this even occurs when the size or quantity of the resources is irrelevant for forming a successful coalition, for instance, when two weaker players do not need a strong player to obtain the collective payoff. However, what is clearly different from our findings is that in coalition formation, the player with more resources often ends up with a lower payoff than the player with less resources. After all, due to the stronger player's higher demands, people often prefer to form coalitions with weak players instead of strong ones, thereby excluding strong players from coalitions. In the coalition formation literature (see e.g., Caplow, 1956; Murnighan, 1978), this finding has been termed the "strength-is-weakness" effect.

One might wonder why we did not find such a strength-is-weakness effect in our research, while we did observe that players with more resources had higher demands (and earned more). To understand the difference, it is important to realize that in coalition formation games, players can obtain high outcomes by excluding one another. In our game, by contrast, Buyers needed to make a deal with both Sellers to obtain the whole puzzle, and only then would they obtain a bonus. As such, one could argue that players in coalition formation games overall have more power over one another than players in our Anticommons Bargaining Game, and that this might explain why the strength-is-weakness effect only occurs in coalition formation games. This does not mean that the Sellers in our game who had less puzzle pieces were less powerful than those with many pieces, or less important to the Buyer. After all, both Sellers (and their asking prices) were equally important for the Buyer to obtain the full puzzle, and were thus both equally pivotal to achieve a successful deal. Actual power differences between the two Sellers may thus not explain why – in our game –Sellers with more puzzle pieces made more money than Sellers with less puzzle pieces. However, we cannot rule out that Sellers with less puzzle pieces did have a subjective "sense" that they had less power than Sellers with more puzzle pieces, which might have influenced their asking prices. The influence of such a psychological sense of power (Anderson, John, & Keltner, 2012; Sekścińska, Rudzinska-Wojciechowska, & Kusev, 2022) on bargaining for complementary resources – and on the behavior and outcomes in anticommons dilemmas – might be another interesting avenue for future research.

Another related point worth addressing, is that in many real-world settings, there may be alternatives for specific complementary resources. For instance, when a tech company wants to produce a new PC, it has to make a decision about which microprocessor to use, as a PC without a processor is useless. In that case, the tech company can choose between processors from several different suppliers, such as Intel or AMD. If, in that case, one of the suppliers has too high demands, the tech company might choose to go to a competitor. In future studies, it would be interesting to use a game that mimics such a setting in which a complementary resource can be substituted by another complementary resource, owned by a different Seller and introduce competition between Sellers. In that case, we might actually find that also in anticommons situations – in which a specific complement can be substituted by another party's complement – a strength-is-weakness effect can occur.

Another question that future research could investigate concerns the boundary condition of the more-is-better heuristic in anticommons situations. In other words, when will people treat complementary resources as complementary, and not as if they are non-complementary? As we showed in our studies, the size or degree of the inequality did not provide such a boundary condition. As such, one may wonder which other circumstances might prevent Sellers and Buyers from using this heuristic when dealing with complementary resources. Related to this, Dhont et al. (2012) posed the question as to whether making people more aware of the externalities of their decisions might help solve the tragedy of the anticommons. In their studies, they indeed demonstrated that externality awareness made people more cooperative in anticommons dilemmas, thereby decreasing the chance of a tragedy occurring. One could increase the salience of complementarity by making small changes to the setup of the Anticommons Bargaining Game. For instance, shuffling the roles of the players in between rounds (e.g., Seller 1 first owning the smaller part of the puzzle and in the next round the larger part) might make them realize that the payoff structure remains exactly the same, irrespective of the size of the part they own. Another possibility is to look at whether cognitive abilities play a role in anticommons dilemmas, for instance, by measuring participants' cognitive reflection capabilities (Frederick, 2005) and see how they predict the use of heuristics in such settings. Such additions might be interesting avenues for future research and might give us new insights into how people deal with anticommons situations.

The question we set out to answer in this paper was whether the size or quantity of complementary resources affects behaviors and outcomes in anticommons dilemmas. The Anticommons Bargaining game that we designed was specifically developed to investigate this, and allowed us to vary the quantity of the resources, by giving the two Sellers more or less puzzle pieces. The paradigm would also allow for alternative ways to study our reasoning. One could, for example, vary the size of the puzzle pieces and provide each Seller with one piece, but with one piece being visually larger than the other. This would be another interesting avenue for future research to test whether using such a visual manipulation of resource size (instead of quantity) would yield a similar kind of heuristic as the one we found in the present study.

To summarize, we showed how a seemingly irrelevant characteristic, quantity, in bargaining for complementary resources influences both Buyers' and Sellers' prices. Our results indicate that people have difficulties in evaluating complementary resources, resources that only generate value if obtained together. People seem to impose the logic of non-complementary resources to complimentary resources, treating each resource as if it has an independent intrinsic value. Yet, since Buyers and Sellers likewise use this logic and coordinate on it over time, we only found partial evidence that such a valuation heuristic impedes successful trade or leads to more frequent underuse of the commons. One implication of our finding is that obtaining several pieces of a complementary resource, like in the case of "patent-hoarding", may be worthwhile, since Buyers are willing to pay a higher price for higher quantities, even if only the whole and not its parts matters in the end.

[1] The mixed model regressions we use throughout this paper specifically model nested data structure and take into account autocorrelations across individuals within a group and across rounds (by allowing the intercept to vary between groups and/or individuals).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. This project has received funding from the European Union (European Research Council Grant 101039296, awarded to Jörg Gross).

Data availability

All data-files and R-scripts used in this paper can be accessed at: https://osf.io/grwhf/?view_only=f0a1efe2ad784195bd60f4ae12b1457e.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.joep.2023.102653.

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