Changing Preferences: An Experiment and Estimation of Market-Incentive Effects on Altruism

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Abstract

This paper studies how altruistic preferences are changed by markets and incentives. We conduct a laboratory experiment with a within-subject design. Subjects are asked to choose health care qualities for hypothetical patients in monopoly, duopoly, and quadropoly. Prices, costs, and patient benefits are experimental incentive parameters. In monopoly, subjects choose quality by trading off between profits and altruistic patient benefits. In duopoly and quadropoly, subjects play a simultaneous-move game. Uncertain about an opponent's altruism, each subject competes for patients by choosing qualities. Bayes-Nash equilibria describe subjects' quality decisions as functions of altruism. Using a nonparametric method, we estimate the population altruism distributions from Bayes-Nash equilibrium qualities in different markets and incentive configurations. Competition tends to reduce altruism, but duopoly and quadropoly equilibrium qualities are much higher than monopoly. Although markets crowd out altruism, the disciplinary powers of market competition are stronger. Counterfactuals confirm markets change preferences.

Keywords: preferences, altruism, markets, incentives

JEL: C14, C57, C72

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1 Introduction

Recent economic research has questioned whether high-powered incentives must result in more outputs or worker efforts. Besides interests in financial reward and effort disutility, economic agents may be fair minded, altruistic, but may also be spiteful. These broad perspectives are particularly important in the health market. Provider altruism and professionalism have been shown to be critical in understanding markets and incentives, in theoretical models, empirical and field works, as well as experiments.

The usual research methodology says that given multi-dimensional preferences, economists can write analytical and empirical models to study markets and incentives. No matter how social preferences are determined, if they remain exogenous, the usual methodology remains valid. In this paper, we assess whether social preferences can be changed by markets and incentives; in other words, we assess if preferences differ across contexts and domains.[1] Our focus is on altruism, market competition, and incentives in health care. We present experimental evidence that altruistic preferences can be diminished by competition and altered by incentives. The usual research methodology may be invalid.

Our research proceeds in three steps. First, in the key conceptual starting point, we use a structural model to decompose behavioral changes into preference effects and market-incentive effects. We explicitly allow altruistic preferences to change according to markets and incentives. Behavioral changes are then results of markets and incentives changing preferences as well as equilibria.

Second, we use a laboratory experiment in which incentives and market competition are exogenously varied. Such an environment offers a better chance for us to identify preferences than real data. The experimental framing is health care provision. Subjects are primed in a decision situation for other-regarding concerns. They choose health care qualities which affect their own payoffs and which benefit patients through a transfer to a charity for actual ophthalmic treatments. We also have taken care to insulate subjects, so such confounding factors as fairness, collusion, and spitefulness were minimized. Each subject experiences different markets and incentive configurations. Our within-subject design is appropriate because we claim that preferences change, not just that preferences are heterogenous (which could be identified by a between-

[1] See, for example, Barseghyan et al. (2011) and Einav et al. (2012).

subject design).

Third, we adapt the nonparametric econometric method by Guerre et al. (2000) to estimate preference distributions. We estimate subjects' altruism distributions separately as subjects experience different market-incentive configurations. The nonparametric method does not restrict us to prespecified distribution classes.

We show that subjects become less altruistic when they have to compete against others in a duopoly or a quadropoly, compared to when they are monopolists. The flip side is that when subjects become monopolists, they become more altruistic. Our contribution can be likened to the classic Lucas critique in policy evaluations. Structural preference parameters vary according to competition and incentives. Equilibrium outcomes depend on both policy and preference changes.

For the theoretical model, we specify that a subject's preferences are given by a weighted average of patients' benefits from health care quality and profits. By choosing a higher quality, the subject reduces profit, but raises patient benefits. A more altruistic subject puts a higher weight on patients' benefits. The tradeoff between benefits and profits depends on three experimental parameters: a subject's price (revenue) per patient, quality cost, and patient benefit.

A subject makes decisions in three markets: monopoly, duopoly, and quadropoly. Under monopoly a subject chooses the quality for the entire patient population. Under duopoly and quadropoly, subjects move simultaneously and each subject's market share depends on the entire profile of subjects' quality choices, according to a logistic demand function. A total of 361 subjects participated in experimental sessions in October 2017 and April 2018 at the University of Cologne. Within each of three markets, we vary incentives using a $2 \times 2 \times 2$ factorial design. Price, cost, and patient benefit assume binary values for a total of eight incentive configurations. In total, each subject plays 24 games.

Each basic game is modelled as one of incomplete information. A player's altruism is his own private information, so each player is uncertain about other players' altruism. Uncertainty is described by a distribution, which, through subjects' play of a Bayes-Nash equilibrium, results in actual qualities. Inverting the Bayes-Nash equilibrium strategy, we estimate the altruism distribution, one for each of the 24 games.

Nonparametric estimations yield very different altruism distributions for the 24 games. The striking pattern is that for each incentive configuration, estimated altruism distributions exhibit lower means in duopoly relative to monopoly, and yet even lower means in quadropoly. Subjects have become less altruistic and value profits more when the market becomes more competitive. What is more striking, however, is that the observed equilibrium qualities are much higher in duopoly and quadropoly than monopoly. Although subjects have become less altruistic, competition disciplinary force is stronger.

These results offer a deeper interpretation than the usual, reduced-form approach. If only behavioral results are considered, then markets and incentives are shown to raise qualities, so one would conclude against crowding out. We reject the simplistic conclusion. Quality changes result from two effects: preference changes and market-incentive changes. The effects go in opposite directions. Market competitions reduce altruism, but also incentivize subjects. Market-incentive effect is stronger than preference-change effect in the experiment. The structural approach permits some counterfactual calculations. It also allows straightforward robustness checks.

It has not escaped our notice that the ultimate questions are: why has competition, according to our evidence, diminished altruism, and why has the competitive disciplinary effect turned out to be stronger? These questions, perhaps, strike a counterpoint to the usual exogenous assumptions for analysis of economic models. Recent advances in neuroscience have adopted a reductionist principle that all behaviors can be traced to brain electrochemical activities. We are neither in a position to render an opinion nor did we manage to use brain scans to detect neural activities. However, we can speculate. When subjects play monopoly, they only have to consider a tradeoff between profits and patient benefits. When subjects play duopoly, they are presented with an additional concern: the competitor's quality choice. The tradeoff between profits and patient benefits now depends on what the rival subject would choose. Complexity has increased, and perhaps the higher cognitive demand has diluted the concern for patient benefits. Perhaps competition has emphasized strategic plays more than altruistic concern towards patients.

The plan of the paper is as follows. The next subsection is a literature review. The model is set up in Section 2. The experimental design and sessions are described in Section 3. In Section 4, we present quality choice descriptive statistics, the nonparametric estimator, and then estimation results on altruism.

We also perform nonparametric tests on the equality of the estimated altruism distributions. We end the section with some counterfactual quality estimations, and a discussion of our method. Section 5 presents the reduced-form analysis. The last section draws some conclusion. Appendix A contains experiment materials. Appendix B collects numerical estimates of altruism parameters, and statistical tests. Appendix C contains robustness checks; we consider an alternate utility function, and a between-subject subsample. An Online Appendix contains supporting materials.

1.1 Literature review

We contribute to recent literature on markets' effects on prosocial-moral behavior. Falk and Szech (2013) show that bilateral and multilateral market interactions reduce morals compared to individual decisions; they attribute this to subjects willing to accept a negative market externality. Bartling et al. (2015, 2019) report less socially responsible behavior in posted-price markets compared to non-market contexts. For markets with negative externalities, Kirchler et al. (2016) analyze how characteristics in double auctions influence moral behavior and Sutter et al. (2020) report that moral costs decreases trading volume.

Some recent experimental evidence disputes the above findings. Bartling et al. (2023) report that repeated play rather than market interaction causes moral erosions.[2] This is also supported by recent theoretical work on markets and social preferences. Dufwenberg et al. (2011) show that individuals with other-regarding preferences behave like selfish individuals in a Walrasian equilibrium with given prices. Dewatripont and Tirole (2022) focus on how market interactions affect individuals' tradeoffs between profits and moral concerns. Whereas market interactions, in their setup, do not change preferences, competition can erode equilibrium ethics when suppliers have heterogenous concerns.

Preferences are typically inferred from observed behaviors in the experimental market games. This method is natural in single-person decisions. However, we consider multi-person strategic interactions. Equilibrium outcomes depend on preferences and market. Our contribution is a method to decompose behavioral changes into those due to preference and market changes. Our approach is probably quite close to Bartling et al. (2015), who structurally estimate consumers' preferences. Whereas they find that the

[2] For further discussion of Falk and Szech's (2013) results, see Breyer and Weimann (2015).

average buyer cares for a third-party's earnings, preference estimates remain unchanged in different market treatments. In their setup, however, consumers and firms do not engage in a strategic game.

Besides potential market effect, economic incentives are often found to reduce prosocial behavior (e.g., Bowles and Polania-Reyes, 2012). Some experimental evidence tends to confirm crowding out (e.g., Gneezy and Rustichini, 2000; Falk and Kosfeld, 2006; Mellström and Johannesson, 2008). Our paper, however, goes beyond identifying crowding out only in terms of outcomes. Incentive schemes are disciplinary, even when they may erode social motives. Incentives and social motives pull in different directions, and it is an empirical matter which is stronger.

With our structural estimation-approach, we relate to studies measuring social preferences such as inequality aversion and reciprocity (e.g., Charness and Rabin, 2002; Bellemare et al., 2008), and altruism from experiments (e.g., Andreoni, 1989; Andreoni and Miller, 2002; Fisman et al., 2007).[3] A few studies use *parametric* structural estimation approaches to measure altruism from experiments in health contexts or with medical students and physicians (Godager and Wiesen, 2013; Wang et al., 2020; Li et al., 2017, 2022; Li, 2018; Attema et al., 2023). These studies report heterogeneity in altruism, none accounts, however, for the influence of competition.

Finally, our (reduced form) analysis relates to the health economics literature on competition and quality. Brekke et al. (2011) show that, with semi-altruistic providers, competition may have ambiguous effects on hospital quality. In an experimental study backed by theory, Brosig-Koch et al. (2017a) report that the market effect depends on individuals' concern for patients' health benefits. Some empirical studies seem to support the positive effect of competition on quality (e.g., Gravelle et al., 2019; Dietrichson et al., 2020). Scott et al. (2022), however, find mixed effects of competition and rather emphasize the importance of differences in demand, costs, and profit. These findings resonate with our reduced form analyses. Keeping patient demand constant, we find that higher prices increase quality and higher costs reduce quality.

[3]For an excellent summary, see DellaVigna (2018). Using data from field experiments, a few papers structurally infer social preferences to identify differences between charitable giving and worker effort; see DellaVigna et al. (2012) and DellaVigna et al. (2022).

2 A model of altruism and competition

Subjects in the experiment role play providing medical services at some quality to patients.[4] The three markets are monopoly, duopoly, and quadropoly. The monopoly game is a single-person decision problem, and the simultaneous-move duopoly and quadropoly games are strategic problems.

Physician providing costly care quality is likened to physician exerting costly efforts. In the course of a treatment, a physician has to plan, execute, and follow-up with patient care. In our experimental design, qualities may refer to physician effort. However, qualities or efforts are not directly paid for because they are non-contractible. Quality provision is driven entirely by altruism in monopoly, and, additionally, by competition in duopoly and quadropoly.

2.1 Quality choices and preferences

A subject receives a fixed payment $p > 0$ for each patient that he or she treats. A subject's quality choice is a continuous variable between 0 and 10. The subject bears the per-patient quality cost at cq^2 when he provides medical service at quality q, where $c > 0$ is a cost parameter. Medical service at quality q gives a benefit bq to a patient, where $b > 0$ is the benefit parameter. We call the environment defined by the three parameters, payment p, cost c, and benefit b, an *incentive configuration.*

Given the altruistic framing, we let a subject's preferences be $\alpha bq + U(p - cq^2)$, for some parameter α and an increasing and concave function U, so preferences are linear combinations of the patient benefit bq, and the utility of the subject's own profit $U(p - cq^2)$. Framing and priming affect subjects differently; accordingly, the preference weight on patient benefit, α, is a random variable on an interval $[\underline{\alpha}, \overline{\alpha}] \subset \mathbb{R}$ with some distribution.

[4]There were no real patients in the laboratory, and the subjects were not medical doctors. We operationalized the quality of medical services by converting it to actual cash payments that benefited real patients outside of the laboratory; see footnote 5 and the end of Subsection 3.1.

2.2 Demand

There are 100 patients who are to receive medical services. Under monopoly, each subject makes a quality decision, q between 0 and 10, for all patients. In duopoly and quadropoly, subjects choose qualities simultaneously. Subjects' quality profile determines subjects' logistic demands. Let q_1 and q_2 be qualities chosen by subject 1 and subject 2 in a duopoly. The numbers of patients for subjects 1 and 2 are, respectively,

$$\frac{100\exp(bq_1)}{\exp(bq_1)+\exp(bq_2)} \quad \text{and} \quad \frac{100\exp(bq_2)}{\exp(bq_1)+\exp(bq_2)}. \tag{1}$$

For quadropoly, let q_1, q_2, q_3, and q_4 denote the four subjects' quality choices. Subject i who chooses quality q_i will have

$$\frac{100\exp(bq_i)}{\exp(bq_1)+\exp(bq_2)+\exp(bq_3)+\exp(bq_4)} \tag{2}$$

patients. The logistic demand guarantees that each subject gets some patients under any quality profile, and is commonly used for discrete-choice situations when consumers' utilities may be subject to noises according to type I extreme-value distribution.

2.3 Monopoly, duopoly and quadropoly

In monopoly, a subject's per-patient payoff is $\alpha bq + U(p - cq^2)$. A profit-maximizing subject (whose α is set at 0) chooses $q = 0$, whereas a subject who only cares about patient benefit chooses the maximum quality, $q = 10$. Generally, a subject's optimal quality is given by the first-order condition:

$$\alpha b - U'(p - cq^2) \times 2cq = 0, \tag{3}$$

which defines a monotone relationship between α and the optimal quality:

$$\alpha = U'(p - cq^2) \times \frac{2cq}{b}. \tag{4}$$

A more altruistic subject is willing to forgo more profit for a higher patient quality. Given a utility function U, equation (4) allows us to infer the value of α from subjects' quality choices.

Subjects also play the duopoly and quadropoly games; we lay out details in duopoly, but will be rather succinct in quadropoly. In duopoly, two subjects are randomly paired. They simultaneously choose qualities, say q_1 and q_2, which result in market shares in (1). The subjects' payoffs are

$$[\alpha_1 bq_1 + U(p - cq_1^2)] \times \frac{100\exp(bq_1)}{\exp(bq_1)+\exp(bq_2)} \quad \text{and} \quad [\alpha_2 bq_2 + U(p - cq_2^2)] \times \frac{100\exp(bq_2)}{\exp(bq_1)+\exp(bq_2)},$$

where α_1 and α_2 are the subjects' altruism parameters.

Duopoly is modelled as a Bayesian game. We let each subject' altruism parameter, α, be drawn independently from a random variable with distribution F and density f on support $[\underline{\alpha}, \overline{\alpha}]$. Each subject observes his own altruism parameter, but not an opponent's altruism parameter. The uncertainty on the altruism parameter α is the basis for the Bayesian perspective.

A subject's strategy is a function that maps the altruism parameter α to a quality, say, $q : [\underline{\alpha}, \overline{\alpha}] \to [0, 10]$. If subject 1 has altruism parameter α_1 and chooses q_1 when the rival subject 2 follows a strategy $q' : [\underline{\alpha}, \overline{\alpha}] \to [0, 10]$, subject 1's expected utility is

$$\begin{aligned} \mathrm{EU}(q_1; q') &= \int_{\underline{\alpha}}^{\overline{\alpha}} \left\{ [\alpha_1 bq_1 + U(p - cq_1^2)] \left[\frac{100\exp(bq_1)}{\exp(bq_1)+\exp(bq'(x))} \right] \right\} \mathrm{d}F(x) \\ &= [\alpha_1 bq_1 + U(p - cq_1^2)] \times \int_{\underline{\alpha}}^{\overline{\alpha}} 100 S(q_1; q'(x)) \mathrm{d}F(x), \end{aligned} \tag{5}$$

where $S(q_1; q') \equiv \dfrac{\exp(bq_1)}{\exp(bq_1)+\exp(bq')}$ denotes the market share, which is uncertain due to the rival subject's stochastic altruism and hence his quality choice. A subject choosing a higher quality earns a higher market share:

$$\frac{\mathrm{d}S(q_1; q')}{\mathrm{d}q_1} = bS(q_1; q')[1 - S(q_1; q')] > 0$$

In duopoly, even a purely profit-maximizing subject ($\alpha = 0$) has an incentive to offer quality because a higher quality gains market share which generates profits. The expression in (5) only concerns those patients the subject serves. Remark 3 at this end of this subsection discusses this specification, and the Online Appendix further provides mathematical details.

For each value of $\alpha_1 \in [\underline{\alpha}, \overline{\alpha}]$, we let

$$q(\alpha_1; q') = \underset{q_1}{\operatorname{argmax}} [\alpha_1 bq_1 + U(p - cq_1^2)] \times \int_{\underline{\alpha}}^{\overline{\alpha}} 100 S(q_1; q'(x)) \mathrm{d}F(x) \tag{6}$$

be subject 1's best response against the rival's strategy $q'(\alpha) : [\underline{\alpha}, \overline{\alpha}] \to [0, 10]$. A subject's optimal quality choice is still a tradeoff between profit and patient benefit. However, a subject's payoff depends on what he believes about his rival subject's qualities, which are chosen according to the strategy q'. A symmetric Bayes-Nash equilibrium strategy specifies a subject's quality choice for each value of the altruism parameter that maximizes the subject's expected utility, given that the rival subject uses the same strategy. We discuss asymmetric Bayes-Nash equilibria in Subsection 4.6.

Definition 1 (Duopoly Bayes-Nash Equilibrium) *The strategy $q^* : [\underline{\alpha}, \overline{\alpha}] \to [0, 10]$ is a symmetric Bayes-Nash equilibrium, if, at each $\alpha \in [\underline{\alpha}, \overline{\alpha}]$,*

$$q^*(\alpha) = \underset{q}{\operatorname{argmax}} \ [\alpha bq + U(p - cq^2)] \times \int_{\underline{\alpha}}^{\overline{\alpha}} 100S(q; q^*(x))\, dF(x). \tag{7}$$

The usual characterization of an equilibrium is by means of the first-order condition for the maximization of (5) or the best response in (6). Given a rival's strategy q', for the maximization of expected utility in (5), we obtain the first-order derivative with respect to q_1:

$$\begin{aligned}\frac{\partial\, \mathrm{EU}(q_1; q')}{\partial q_1} &= [\alpha_1 b - 2cq_1 U'(p - cq_1^2)] \times \int_{\underline{\alpha}}^{\overline{\alpha}} 100S(q_1; q'(x))\mathrm{d}F(x) \\ &+ [\alpha_1 bq_1 + U(p - cq_1^2)] \times \int_{\underline{\alpha}}^{\overline{\alpha}} 100bS(q_1; q'(x))[1 - S(q_1; q'(x))]\mathrm{d}F(x). \end{aligned} \tag{8}$$

By setting the first-order derivative to zero, we obtain the implicit function that defines the best response at α.

At the symmetric Bayes-Nash equilibrium, $q^* : [\underline{\alpha}, \overline{\alpha}] \to [0, 10]$, each subject has the same first-order condition, so it is given by setting (8) to 0 at each $\alpha \in [\underline{\alpha}, \overline{\alpha}]$ with q' set to q^*:

$$\begin{aligned} &[\alpha b - 2cq^*(\alpha)U'(p - cq^*(\alpha)^2)] \times \int_{\underline{\alpha}}^{\overline{\alpha}} 100S(q^*(\alpha); q^*(x))\mathrm{d}F(x) \\ &+ [\alpha bq^*(\alpha) + U(p - cq^*(\alpha)^2)] \times \int_{\underline{\alpha}}^{\overline{\alpha}} 100bS(q^*(\alpha); q^*(x))[1 - S(q^*(\alpha); q^*(x))]\mathrm{d}F(x) = 0. \end{aligned} \tag{9}$$

Being the solution of an integral equation, a symmetric Bayes-Nash equilibrium is difficult to compute, even for simple functional forms of the utility U and distribution F. Fortunately, we do not have to rely on this computation. In fact, what makes our model operational is the following.

Lemma 1 *Equilibrium strategy $q^* : [\underline{\alpha}, \overline{\alpha}] \to [0, 10]$ is monotone increasing in α.*

Proof of Lemma 1: Using the first-order derivative of EU with respect to q_1 in (8), we further differentiate this with respect to α_1 to obtain

$$\frac{\partial^2 \mathrm{EU}(q_1;q')}{\partial\alpha_1\partial q_1} = b\int_{\underline{\alpha}}^{\overline{\alpha}} 100S(q_1;q'(x))\mathrm{d}F(x) + bq_1\int_{\underline{\alpha}}^{\overline{\alpha}} 100bS(q_1;q'(x))[1-S(q_1;q'(x))]\mathrm{d}F(x) > 0.$$

By assumption EU is quasi-concave in q_1, so as α_1 increases, the optimal quality increases. This is true for any given strategy q', so remains valid at the equilibrium q^*.■

Because α is a random variable, the equilibrium strategy $q^*(\alpha)$ is also a random variable. The following describes how we will use the equilibrium play data.

Remark 1 (Duopoly Equilibrium Quality Distribution) *The Bayes-Nash equilibrium q^* induces a joint distribution of the two subjects' equilibrium qualities on $[0,10]\times[0,10]$. By symmetry and independence, the marginal density is the one induced by the equilibrium strategy q^*. Denoting this marginal distribution by $G^*:[0,10]\to[0,1]$, we conclude that for $\widetilde{q}\in[0,10]$, $G^*(\widetilde{q}) = F(\widetilde{\alpha})$, where $q^*(\widetilde{\alpha}) = \widetilde{q}$.*

The actual play of the duopoly are realizations of G^*. By the monotonicity of the equilibrium q^*, the distribution F of α and the equilibrium quality distribution G^* are isomorphic. Whereas we have no data on F, we do have data on qualities from equilibrium play. This is the key to the estimation of the altruism distribution F under duopoly, and Subsection 4.2 will present the estimation of G^* by the empirical quality distribution.

Next, we discuss quadropoly. There are now four subjects, and the demands are in (2). Otherwise, there is no conceptual difference between duopoly and quadropoly. The definition of a symmetric Bayes-Nash equilibrium has exactly the same form. If subject i chooses quality q_i, her market share now is $S(q_i;q_{-i}) = \dfrac{\exp(bq_i)}{\sum_{j=1}^4 \exp(bq_j)}$, where we use q_{-i} to denote the quality vector (q_1,q_2,q_3,q_4) with the i^{th} element omitted. Given strategies q_j, $j=1,2,3,4$, $j\neq i$, if subject i chooses quality q_i at α_i, the expected utility is

$$\left[\alpha_i b q_i + U(p-cq_i^2)\right]\times\int\int\int 100S(q_i;q_{-i}(\alpha_{-i}))\prod_{j=1,\ j\neq i}^{4}\mathrm{d}K(\alpha_j),$$

where the notation $q_{-i}(\alpha_{-i})$ is a short hand for $(q_j(\alpha_j),\ j=1,2,3,4,\ j\neq i)$, and K is the distribution of α in quadropoly.

Definition 2 (Quadropoly Bayes-Nash Equilibrium) *The strategy $q^{**}(\alpha)$ is a symmetric Bayes-Nash equilibrium, if, at each $\alpha \in [\underline{\alpha}, \overline{\alpha}]$,*

$$q^{**}(\alpha) = \underset{q}{\operatorname{argmax}} \ \left[\alpha b q + U(p - cq^2)\right] \int\int\int \left\{100 S(q; q^{**}_{-i}(\alpha_{-i}))\right\} \prod_{j=1,\ j\neq i}^{4} dK(\alpha_j). \tag{10}$$

We can use the first-order condition to characterize the equilibrium strategy q^{**}. It is straightforward to verify the same monotonicity property.

Lemma 2 *Equilibrium strategy $q^{**} : [\underline{\alpha}, \overline{\alpha}] \to [0, 10]$ is monotone increasing in α.*

Remark 2 (Quadropoly Equilibrium Quality Distribution) *The Bayes-Nash equilibrium q^{**} induces a joint distribution of the four subjects' equilibrium qualities on $[0, 10]^4$. By symmetry and independence, the marginal density is the one induced by the equilibrium strategy q^{**}. We denote this marginal distribution by $L^{**} : [0, 10] \to [0, 1]$.*

Although we have the same set of subjects in 3 markets and 8 incentive configurations, we do allow altruism distributions to vary according to markets and incentive configurations.

Remark 3 (Extended Concern) *We would like to comment on the altruistic expected utility specification in (5). An alternate view could be that a subject might enjoy some utility even if a patient was treated by a rival subject. If a rival offers q', the subject's expected utility from offering quality q_1 is now written as $S(q_1; q')[\alpha b q_1 + U(p - cq_1^2)] + [1 - S(q_1; q')]\beta b q'$, where β is a parameter for valuing patient's benefit from the rival's quality. This "extended concern" perspective (the β valuation of rival quality) has not been used before as far as we know. Prior research on altruistic providers in Brekke et. al. (2011) and Brosig-Koch et. al. (2017a), for example, use altruistic preferences similar to ours in (5). Perhaps, the reason is this. When subjects compete, an extended concern actually may reduce quality incentives because a subject tends to free-ride on the rival's quality. This amounts to an unnatural perspective: altruism and free-riding coexist. We provide the details in the Online Appendix.*

3 The experiment

3.1 Design

The experimental design implements the theoretical model. Role playing as physicians, subjects decide on the quality of health care for hypothetical patients.[5] Each subject chooses a medical-service quality q from a set $\{0, 1, 2, \ldots, 10\}$, rather than the continuous interval $[0, 10]$ as in the theoretical model. Three parameters determine payoffs: price to the physician p, cost parameter c, and patient benefit parameter, b. Profit is $p - cq^2$, and the patient benefit is bq.

We use a $2 \times 2 \times 2$ factorial design to vary each of the p, c, and b parameters. The capitation payment p may be low or high, set at 10 and 15, respectively. The cost parameter c can be either 0.075 or 0.1, and the benefit parameter b can be either 0.5 or 1. The full set of parameters are in Table 7 in Appendix A. A profile of price-cost-benefit parameters is called an incentive configuration; the $2 \times 2 \times 2$ variations set up 8 incentive configurations. There are 3 markets: monopoly, duopoly, and quadropoly. Each subject plays 24 games in the experiment: 8 incentive configurations by 3 markets. All monetary amounts were in terms of the experimental currency, Taler, which was later converted to Euro at the rate of 100:1.

The experiment uses a within-subject design. Subjects experience different markets and incentive configurations, and we aim to investigate how subjects' quality choices and preferences change according to their experiences. In the actual implementation, subjects played all 8 incentive-configuration games in one market, and then moved onto the next market. Subjects were not informed of the market up until they were to play the 8 incentive-configuration games in that market.[6]

There are 6 different ways to order the three markets, displayed in Table 1. For example, in "3 (D-Q-M)" a subject plays the duopoly game first, followed by quadropoly, and finally monopoly. We roughly assigned

[5] Hypothetical patient profiles, characterizing patients through different benefits from medical treatment decisions, have been used in several behavioral experiments in health with medical and non-medical students (e.g., Hennig-Schmidt et al., 2011; Kesternich et al., 2015; Brosig-Koch et al., 2017a, 2017b, 2023; Wang et al., 2020; Waibel and Wiesen, 2021) and practicing physicians (e.g., Brosig-Koch et al., 2016, 2023).

[6] It was impractical to get subjects to play the 24 games in a random order. Too much back-and-forth between markets and incentive configurations could be confusing. Random rematching for 16 times for each subject also would be time consuming.

about 1/6 of the subject population to each of the 6 orders. The last column in Table 1 lists the number of subjects who participated in each order. We randomize the order in which the 8 incentive configurations are presented to subjects. In each market, each subject plays the 8 games in the following order: 1st, ($p = 10$, $c = 0.1$, $b = 1$); 2nd, ($p = 10$, $c = 0.075$, $b = 1$); 3rd, ($p = 15$, $c = 0.1$, $b = 0.5$); 4th, ($p = 15$, $c = 0.1$, $b = 1$); 5th, ($p = 10$, $c = 0.1$, $b = 0.5$); 6th, ($p = 10$, $c = 0.075$, $b = 0.5$); 7th ($p = 15$, $c = 0.075$, $b = 1$) and 8th, ($p = 15$, $c = 0.075$, $b = 0.5$).

Table 1: Market orders in the experiment

Condition	Order of markets	Number of subjects
1 (M-D-Q)	Monopoly-Duopoly-Quadropoly	64
2 (M-Q-D)	Monopoly-Quadropoly-Duopoly	60
3 (D-Q-M)	Duopoly-Quadropoly-Monopoly	63
4 (Q-M-D)	Quadropoly-Monopoly-Duopoly	60
5 (Q-D-M)	Quadropoly-Duopoly-Monopoly	58
6 (D-M-Q)	Duopoly-Monopoly-Quadropoly	56
Total		361

The common "random-choice" payment method is used to determine profits and patient benefits. One of the 8 incentive-configuration games in each market would be chosen randomly for determining the subject's profit and the patient benefits. The random-choice payment method was implemented for each subject independently; this avoids income effects and possibly keeps subjects' focus.

Subjects play a normal form game against others randomly drawn from a population. A subject never learns others' decisions for any of the 8 incentive-configuration games in a market. However, at the end of one market session, each subject is given a summary information of actual demands, profits, and patient benefits, aggregated over the 8 games. In duopoly and quadropoly, subjects are randomly paired or grouped. When subjects are done with one market, say duopoly, the match will be dissolved. Then subjects will be randomly matched for the next market, say quadropoly.

Our design rules out repeated plays, learning, and reputation. This is a design tradeoff. On the one hand, as our focus is on altruism, we would like to avoid issues about norms and collusions. On the other hand, we would have to face the possibility that subjects having to learn to play a Bayes-Nash equilibrium. In the end, we have come down with a design that would rely on subjects playing a Bayes-Nash equilibrium with preferences governed by altruism. This explains our suppressing information of subjects' play and outcomes; we have some discussion in Subsection 4.6. We focus on altruism, so it is inappropriate to introduce a control with patient benefits removed, or to make the benefits independent of subjects' quality choices.[7]

We do want to find out if subjects' preferences change according to markets and incentive configurations, hence our within-subject design. However, we can use a subsample for a between-subject design. We construct this subsample by taking data from a subject's experiences in the market he or she first participates. Given that we have 361 subjects, a between-subject design would put only about 120 subjects in one market. The between-subject subsample serves as a comparison with the main within-subject design. The analysis is in Appendix C.2. The results are consistent with the complete sample.

Although there are no real patients, the health benefits accrued in the laboratory are converted into monetary transfers to a charity dedicated to providing surgeries for ophthalmic patients. The patient benefit is thus made salient. A subject's consideration of patients' benefit from costly quality choices have real empirical and health-related consequences.

3.2 Experimental sessions

Experimental sessions took place in October 2017 and in April 2018, at the Cologne Laboratory for Experimental Research of the University of Cologne, Germany. Almost all subjects were students from the University of Cologne. Participants were invited via the ORSEE platform (Greiner, 2015). In total, 361 subjects participated in the experiment.[8] Subjects on average were about 24 years old, with 55% being female. Among the subjects who were students, 131 were in law and social sciences, 22 in medicine, 42 in arts and humanities, 49 in mathematics and natural sciences, 35 in theology. There were 21 in other

[7]To eliminate patient benefit, we would have to write a new set of instructions, and let subjects see different screens in the experiments. It is questionable how such a setup could be construed as any control or variant. Besides, we would not be able to control what subjects would think about what qualities were doing.

[8]We dropped three subjects who did not complete their last, monopoly sessions due to technical problems (one subject in condition 3 (D-Q-M), and two in condition 5 (Q-D-M)). However, these three subjects did interact with other subjects before they played their last monopoly session. We have kept data of others who played against these three subjects in duopoly and quadropoly.

disciplines or non-students; 61 subjects did not provide their faculty information.[9]

The experiment was programmed in zTree (Fischbacher, 2007). Upon arrival, subjects were randomly assigned to cubicles. Initial instructions informed subjects that the experiment consisted of three parts (monopoly, duopoly, or quadropoly). Detailed instructions of each part would only be given at the start of that part. Participants had adequate time to read the instructions. The instructions can be found in Appendix A.1. Participants were allowed to ask clarifying questions, which were answered in private. For each market, subjects needed to answer several control questions. Subjects should understand the price, cost, and benefit parameters, and how quality choices might affect demands. Each subject must answer all control questions correctly before the start of each part. The control questions can be found in Appendix A.2.

When making a decision, each subject was informed of the incentive-configuration parameters, as well as profits and the patient benefits as functions of the quality that can be one in $\{0, 1, 2..., 10\}$. In monopoly, each subject had 100 patients. In duopoly and quadropoly, a subject had a logistic demand which depended on the quality profile of matched subjects. The zTree program provided a calculator, which allowed subjects to practice inputting own and other players' qualities to calculate the resultant demands (number of patients), profits, and patient benefits for all players. A screen shot of the calculator is in Appendix A.3. After subjects played the 8 incentive-configuration games in a market, they were informed of their and their paired subject's or subjects' total demands (number of patients), and total patient benefits in the 8 games. Data about individual games in each incentive configuration were not given.

One subject was randomly chosen to be a monitor. After the experiment, the monitor verified that a money order equal to the total patient benefit was issued by the Finance Department of the University of Cologne. The money order was payable to an organization, *Christoffel Blindenmission*, which supports

[9]We did not recruit medical students only; there were not enough such potential subjects. Some experimental studies indicated differences between medical and non-medical students' responses to financial incentives. Hennig-Schmidt and Wiesen (2014), Brosig-Koch et al. (2016, 2017b), and Reif et al. (2020) show that students with non-medical majors respond somewhat stronger to financial incentives than medical students. However, effects are similar across subject pools. Further, experimental studies in non-market settings reported that medical students are more altruistic than non-medical students or those from a representative US sample (American Life Panel) with comparable ages (Li et al. 2017, 2022; Attema et al. 2023). However, for the 22 medical students in our sample, we observed very similar patterns in quality choices compared to others; they also raise qualities when the market becomes more competitive.

ophthalmologists performing cataract surgeries in a hospital in Masvingo, Zimbabwe. The money order was sealed in an envelope, and the monitor and an assistant then deposited the envelope in a nearby mailbox. The monitor was paid an additional €5. Subjects were told in advance that the experimental patient benefits would be for real patients, but not for those in a developing country to avoid any compassion motives. A similar procedure for making patient benefits meaningful to subjects has been applied by, for example, Hennig-Schmidt et al. (2011), Kesternich et al. (2015), and Brosig-Koch et al. (2017a, 2017b).

Sessions lasted, on average, for about 90 minutes, and subjects earned, on average, about €14.20 (€18.20 including show-up fee). The average benefit per patient was about €8.10. In total, €2,923.60 were transferred to the Christoffel Blindenmission. Average costs for a cataract operation for adults are about €30, so our experiment supported about 100 surgeries.[10]

4 Estimation of altruism distributions from experimental data

We first present data of subjects' quality choices. Then we describe how we estimate structurally the α altruism distribution for each market and in each incentive configuration.

4.1 Descriptive statistics on subjects' quality choices

Table 2 presents some summary statistics of the 361 subjects' quality choices in the 8 incentive-configuration games in the 3 markets. Clearly, subjects on average chose higher qualities in duopoly and quadropoly than in monopoly, and the standard deviations of subjects' quality choices were also much smaller. Raising the intensity of competition from duopoly to quadropoly increases qualities only slightly. Within a market, quality variations between the 8 incentive-configuration games seem quite modest.

[10]For more on activities of the Christoffel Blindenmission related to cataract, see www.cbm.de/spendenCBM_Spenden_Sie_fuer_Operationen_am_Grauen_Star-494570.html.

Table 2: Means and standard deviations of subjects' quality choices

Incentive configurations	Monopoly		Duopoly		Quadropoly	
	mean	st. dev.	mean	st. dev.	mean	st. dev.
($p = 10$, $c = 0.075$, $b = 0.5$)	4.17	2.99	7.75	1.58	8.26	1.40
($p = 10$, $c = 0.075$, $b = 1$)	4.15	2.99	7.98	1.59	8.31	1.56
($p = 10$, $c = 0.1$, $b = 0.5$)	3.79	2.79	6.94	1.35	7.34	1.34
($p = 10$, $c = 0.1$, $b = 1$)	3.73	2.80	7.09	1.52	7.46	1.34
($p = 15$, $c = 0.075$, $b = 0.5$)	4.82	3.43	8.82	1.53	9.09	1.32
($p = 15$, $c = 0.075$, $b = 1$)	4.83	3.41	8.98	1.60	9.15	1.43
($p = 15$, $c = 0.1$, $b = 0.5$)	4.51	3.27	8.19	1.63	8.55	1.47
($p = 15$, $c = 0.1$, $b = 1$)	4.44	3.19	8.40	1.62	8.65	1.61
Total	4.31	3.14	8.02	1.70	8.35	1.57

For each of the 24 games, we draw the quality histograms; they are in Figures 1 to 3, and the actual frequency of each quality between 0 and 10 is written at the top of each vertical bar. The 24 histograms show higher qualities in duopoly and quadropoly than monopoly, but the differences between duopoly and quadropoly appear to be slight. Quality frequencies are needed for the estimation of altruism parameters.

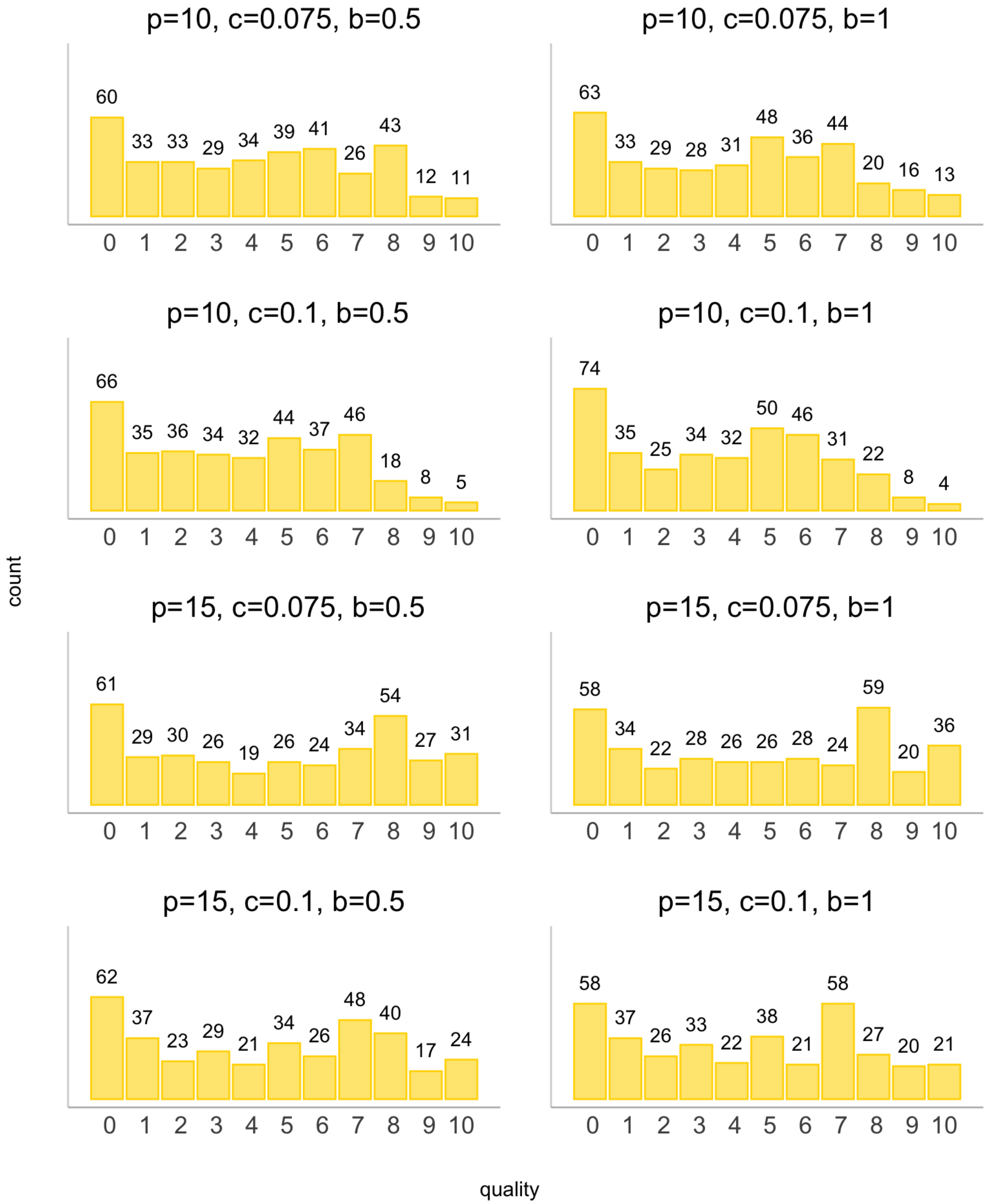

Figure 1: Quality histograms in monopoly

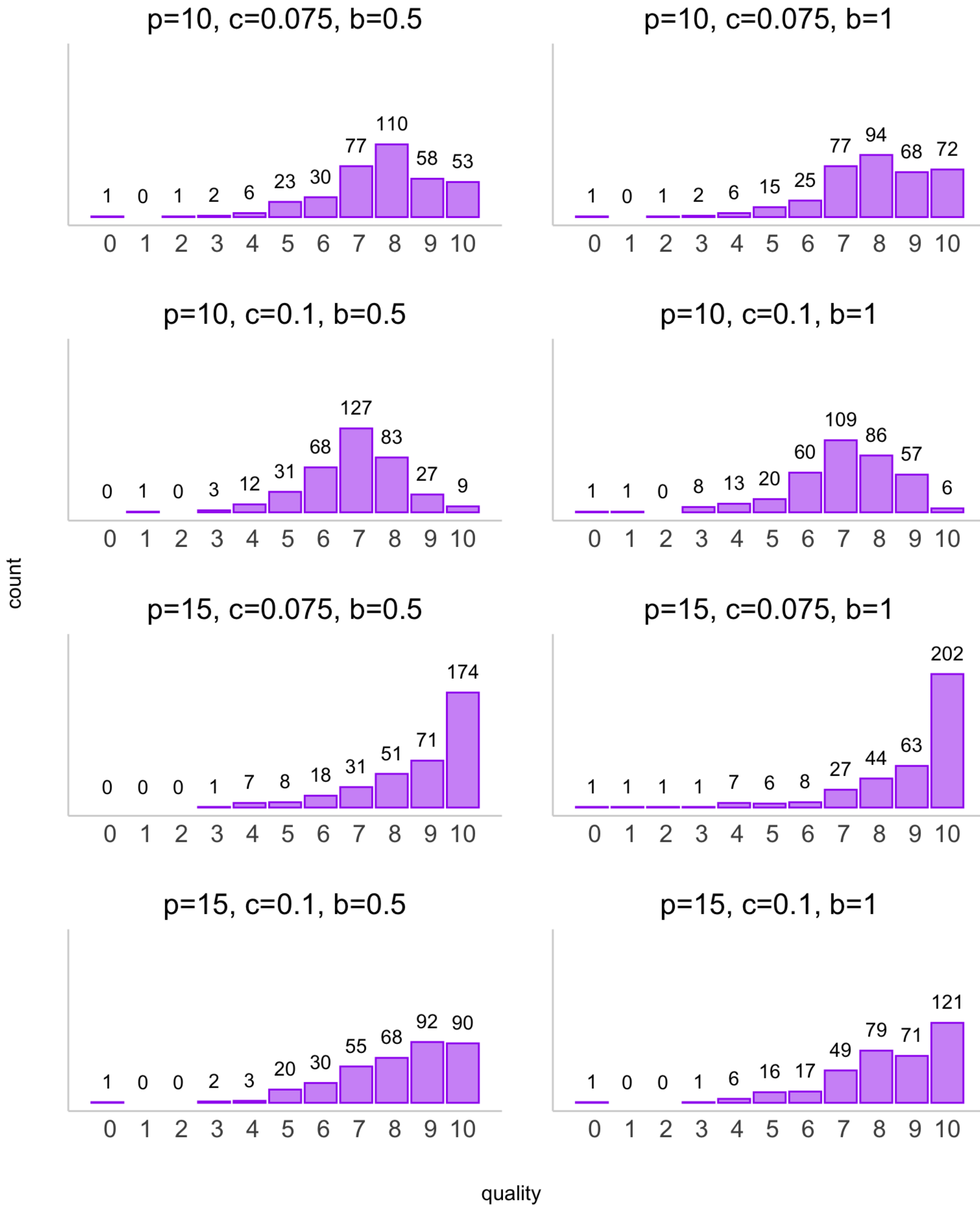

Figure 2: Quality histograms in duopoly

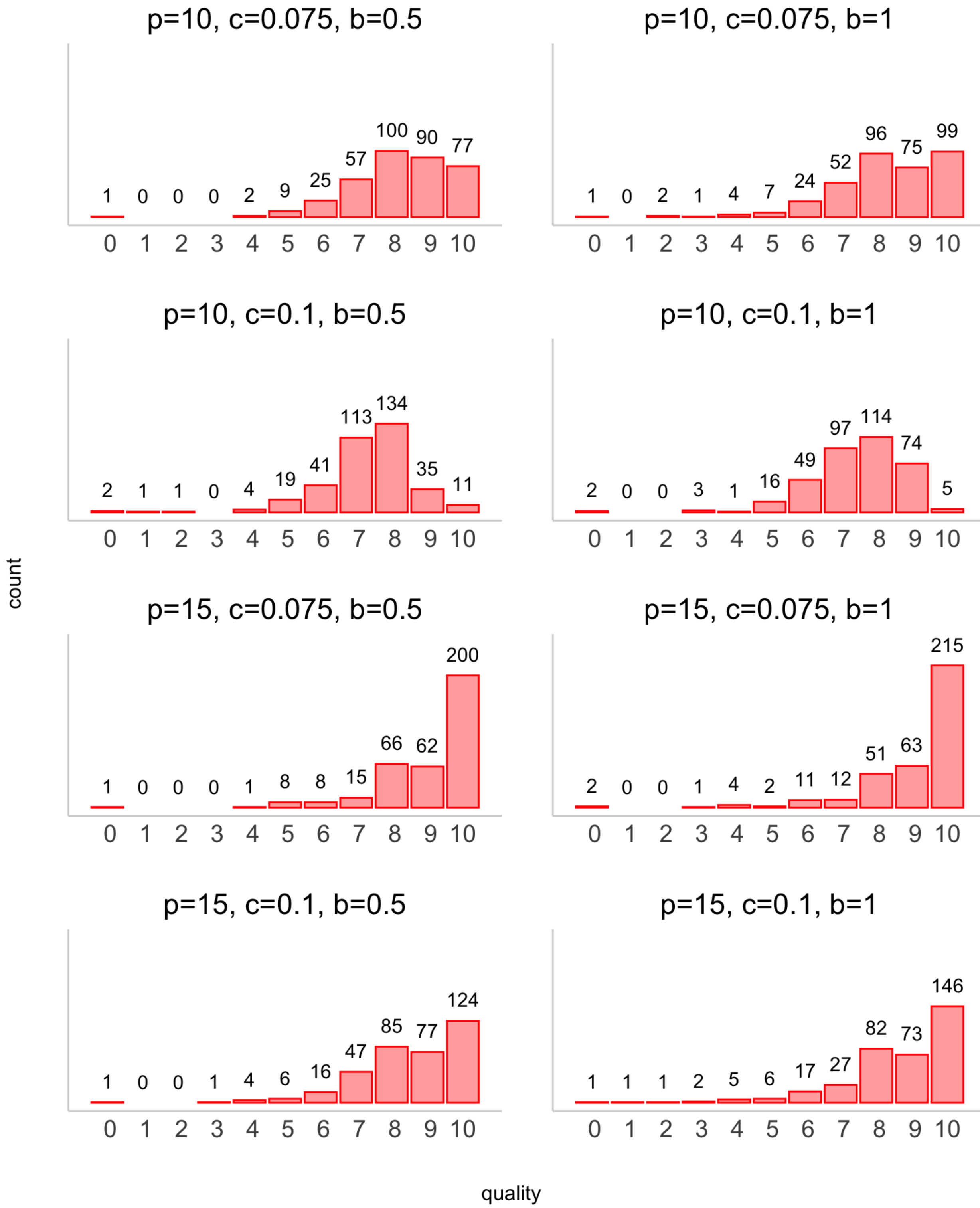

Figure 3: Quality histograms in quadropoly

4.2 Nonparametric estimation of altruism distribution by Bayes-Nash equilibria

We adapt a nonparametric estimation method by Guerre et al. (2000) (abbreviated to GPV) for first-price auctions. It is illustrated here with duopoly and an incentive configuration. First, we invert equilibrium strategy q^* in (9) to obtain α in terms of $q^*(\alpha)$, the utility function U, and incentive parameters:

$$\alpha = \frac{\left\{ \begin{array}{c} 2cq^*(\alpha)U'(p-cq^*(\alpha)^2)\displaystyle\int_{\underline{\alpha}}^{\overline{\alpha}} S(q^*(\alpha);q^*(x))\mathrm{d}F(x) \\ -U(p-cq^*(\alpha)^2)\times\displaystyle\int_{\underline{\alpha}}^{\overline{\alpha}} bS(q^*(\alpha);q^*(x))[1-S(q^*(\alpha);q^*(x))]\mathrm{d}F(x) \end{array} \right\}}{\left\{ \begin{array}{c} b\displaystyle\int_{\underline{\alpha}}^{\overline{\alpha}} S(q^*(\alpha);q^*(x))\mathrm{d}F(x) \\ +bq^*(\alpha)\displaystyle\int_{\underline{\alpha}}^{\overline{\alpha}} bS(q^*(\alpha);q^*(x))[1-S(q^*(\alpha);q^*(x))]\mathrm{d}F(x) \end{array} \right\}}. \tag{11}$$

Given equilibrium q^*, the uncertainty about a rival subject's altruism is equivalent to the uncertainty about the rival's quality choices. From Remark 1, we can replace the altruism distribution F by the equilibrium quality distribution G^*. Then, using q to denote the subject's equilibrium quality at α, we rewrite (11) as

$$\alpha = \frac{2cqU'(p-cq^2)\displaystyle\int_0^{10} S(q;x)\mathrm{d}G^*(x) - U(p-cq^2)\times\int_0^{10} bS(q;x)[1-S(q;x)]\mathrm{d}G^*(x)}{b\displaystyle\int_0^{10} S(q;x)\mathrm{d}G^*(x) + bq\int_0^{10} bS(q;x)[1-S(q;x)]\mathrm{d}G^*(x)}. \tag{12}$$

We estimate the α distribution by recovering their values from subjects' quality choices. The estimated α is a nonlinear map of the chosen quality q and the equilibrium quality distribution G^*.

The two-step GPV method is as follows. In Step 1, the densities of equilibrium quality distribution G^* are estimated by the empirical quality densities. Let $\widehat{g}(x)$ denote the empirical quality densities, fractions of subjects who have chosen quality $x = 0, 1, ..., 10$. We use $\widehat{g}(x)$ to estimate the densities of G^*. The empirical densities of the 24 games are those in Figures 1 to 3.

The terms $\displaystyle\int_0^{10} S(q;x)\mathrm{d}G^*(x)$ and $\displaystyle\int_0^{10} bS(q;x)[1-S(q;x)]\mathrm{d}G^*(x)$ in (12) are estimated by $\displaystyle\sum_{x=0}^{10} S(q;x)\widehat{g}(x)$ and $\displaystyle\sum_{x=0}^{10} bS(q;x)[1-S(q;x)]\widehat{g}(x)$, respectively. For each subject $i = 1, ..., 361$, we use (12) to calculate:

$$\hat{\alpha}_i = \frac{2cq_iU'(p-cq_i^2)\sum_{x=0}^{10} S(q_i;x)\widehat{g}(x) - U(p-cq_i^2)\sum_{x=0}^{10} bS(q_i;x)[1-S(q_i;x)]\widehat{g}(x)}{b\sum_{x=0}^{10} S(q_i;x)\widehat{g}(x) + bq_i\sum_{x=0}^{10} bS(q_i;x)[1-S(q_i;x)]\widehat{g}(x)}, \tag{13}$$

which is an estimate of subject i's α. In Step 2, we use the sample of estimated α's to estimate nonparametrically the altruism distribution:

$$\widehat{F}(a) = \frac{1}{361} \sum_{i=1}^{361} I\{\hat{\alpha}_i \leq a\}. \tag{14}$$

where I is the indicator function that takes the value 1 when the condition inside the curly brackets is satisfied, and 0 otherwise.

The estimation procedures are similar for monopoly and quadropoly. In monopoly, we use the first-order condition (4) to recover a subject's α value from the quality choice: for each $i = 1, ..., 361$, we compute

$$\hat{\alpha}_i = \frac{2cq_i U'(p - cq_i^2)}{b}.$$

Then these estimated α's are used to estimate the distribution of altruism in the second step.

For quadropoly, in the first step, we compute the following

$$\hat{\alpha}_i = \frac{2cq_i U'(p - cq_i^2) \sum_{x,y,z=0}^{10} S(q_i; x, y, z)\widehat{l}(x)\widehat{l}(y)\widehat{l}(z) - U(p - cq_i^2) \sum_{x,y,z=0}^{10} bS(q_i; x, y, z)[1 - S(q_i; x, y, z)]\widehat{l}(x)\widehat{l}(y)\widehat{l}(z)}{b \sum_{x,y,z=0}^{10} S(q_i; x, y, z)\widehat{l}(x)\widehat{l}(y)\widehat{l}(z) + bq_i \sum_{x,y,z=0}^{10} bS(q_i; x, y, z)[1 - S(q_i; x, y, z)]\widehat{l}(x)\widehat{l}(y)\widehat{l}(z)},$$

where $\widehat{l}(x), x = 0, 1, ..., 10$ is the empirical density function of quality in quadropoly. In the second step, these estimated α's are used to estimate the altruism distribution K.

Subjects' maximum quality choice is 10. Some subjects could have hit a corner solution; if quality could go higher than 10, that higher value might have been chosen. We do a robustness check on this possibility. When quality 10 is chosen, we hypothesize that it could be either 10, 11, or 12, with the original density for 10 spread evenly over the qualities 10, 11, or 12. The above estimated α's would then extend to $\widehat{l}(x) = 11, 12$. We perform tests on these hypothetical distributions; the results remain the same and are collected in the Online Appendix.

Given preferences and a symmetric equilibrium, our Bayesian game with independent values is identified by the equilibrium quality being monotone in altruism. GPV's two-step estimator for bidders' valuation distribution in first-price auctions is consistent and achieves optimal convergence rate with a properly chosen bandwidth. These results depend on the assumption that the unknown valuation distribution is smooth. However, subjects in our game choose from only 11 possible qualities. We can only estimate the unknown altruism distribution by histograms with 11 possible values. Even with more subjects, we would be unable to approximate a smooth distribution by histograms with a limited number of values.

4.3 Estimates of altruism distributions

We assume a linear utility function: $U(x) = x$. Then α is the marginal rate of substitution between patient benefit bq and profit $p - cq^2$. For monopoly we have

$$\alpha = \frac{2cq}{b}, \tag{15}$$

for duopoly, we have

$$\alpha = \frac{2cq\int_0^{10} S(q;x)\mathrm{d}G(x) - (p - cq^2) \times \int_0^{10} bS(q;x)[1 - S(q;x)]\mathrm{d}G(x)}{b\int_0^{10} S(q;x)\mathrm{d}G(x) + bq\int_0^{10} bS(q;x)[1 - S(q;x)]\mathrm{d}G(x)}. \tag{16}$$

We omit the corresponding expression for α under quadropoly.

The linear U assumption is an approximation, and has been used in many previous studies, as early as in Ellis and McGuire (1986). The approximation is acceptable when income effects are insignificant. We use a random-choice payment method; only one game out of eight (in each market) is used for payment, so the variation in wealth is quite limited. Nevertheless, we can relax this. In Appendix C.1, we present estimation results for the constant-absolute-risk-aversion (CARA) utility function $U(x) \equiv 1 - \exp(-rx)$.[11] There we set the coefficient of absolute risk aversion r at 0.10. (We have also obtained results for r set at 0.05 and 0.15. Results turn out to be similar and are reported in the Online Appendix.) The drawback is that the marginal rate of substitution between patient benefit and profit varies with the profit, so the estimated value of α is not so easy to interpret.

Table 3 presents the means of the estimated α distributions in monopoly. We use these estimated monopoly means as normalization, which uses the estimated monopoly mean as the origin. In duopoly and quadropoly, for each incentive configuration, we subtract the corresponding estimated monopoly mean

[11] CARA is a common functional form for risk preferences in the literature; see, for example, Barseghyan et al. (2018). It has been used for estimating risk preferences from individual-level data in contexts such as property insurance (Cohen and Einav, 2007; Barseghyan et al., 2016), game shows (Beetsma and Schotman, 2001; Andersen et al., 2008), and health insurance (Einav et al., 2013; Handel and Kolstad, 2015). In experiments, the CARA specification also has been used for estimating risk preferences (Harrison and Rutström, 2008).

Table 3: Estimated means of α in monopoly

Incentive configurations	mean
($p = 10$, $c = 0.075$, $b = 0.5$)	1.252
($p = 10$, $c = 0.075$, $b = 1$)	0.622
($p = 10$, $c = 0.1$, $b = 0.5$)	1.515
($p = 10$, $c = 0.1$, $b = 1$)	0.746
($p = 15$, $c = 0.075$, $b = 0.5$)	1.446
($p = 15$, $c = 0.075$, $b = 1$)	0.725
($p = 15$, $c = 0.1$, $b = 0.5$)	1.805
($p = 15$, $c = 0.1$, $b = 1$)	0.889

from each estimated α. In Table 4, we present the normalized means and standard deviations of the 24 altruism distributions. Due to the normalization, each reported monopoly α distribution in Table 4 has a zero mean. Across a row in Table 4, for example, the magnitude -1.335 for the duopoly α mean in incentive configuration ($p = 10$, $c = 0.075$, $b = 0.5$) says that when the market changes from monopoly to duopoly, the average altruism parameter has decreased by 1.335.

Table 4: Normalized means and standard deviations of α distributions

Incentive configurations	Monopoly		Duopoly		Quadropoly	
	mean	st. dev.	mean	st. dev.	mean	st. dev.
($p = 10$, $c = 0.075$, $b = 0.5$)	0	0.898	-1.335	0.939	-1.579	0.766
($p = 10$, $c = 0.075$, $b = 1$)	0	0.448	-0.812	0.612	-0.985	0.657
($p = 10$, $c = 0.1$, $b = 0.5$)	0	1.117	-1.378	0.903	-2.233	1.710
($p = 10$, $c = 0.1$, $b = 1$)	0	0.559	-0.882	0.725	-1.069	0.822
($p = 15$, $c = 0.075$, $b = 0.5$)	0	1.028	-1.980	0.928	-2.382	0.980
($p = 15$, $c = 0.075$, $b = 1$)	0	0.512	-1.244	0.767	-1.471	1.138
($p = 15$, $c = 0.1$, $b = 0.5$)	0	1.308	-2.001	1.327	-2.428	1.147
($p = 15$, $c = 0.1$, $b = 1$)	0	0.638	-1.207	0.827	-1.485	1.016

Across each row, the average altruism has decreased from monopoly to duopoly, and then decreased further more from duopoly to quadropoly. Competition reduces altruism on average. Standard deviations also tend to be different, but the pattern is not so uniform.

Each of the α estimate is a nonlinear transformation of the chosen quality and the empirical quality distribution, and market and incentive-configuration parameters. We show the histograms of normalized α estimates with overlaid smooth densities in three markets in Figures 4 to 6. Note that we show densities rather than counts in y-axis in these figures, unlike the quality histograms in Figures 1 to 3.

First, start with monopoly α estimates in Figure 4. Due to the nonlinear transformation from the observed qualities to the estimated α, the actual values differ considerably across different incentive configurations.

Nevertheless, these histograms show that altruism distributions are diverse. The normalized α estimates in monopoly are in Table 8 in Appendix B.

Next, we turn to estimated duopoly α (again normalized by the corresponding monopoly mean) shown in Figure 5 and in Table 9 in Appendix B. We do not report those α when the corresponding quality was chosen by none of the subjects. The frequency for each α estimate is the same as the corresponding quality frequency, which is in Figure 2.

The estimated values of α are very different from those in monopoly. The range has become much wider. From the histograms, we see that the higher values of estimated α's have higher densities, but all of these higher values are below the corresponding monopoly mean. Subjects have become much less altruistic. Besides the stronger concentration, the α distributions appear to be strongly left-skewed in duopoly.

Figure 6 and Table 10 in Appendix B present the (normalized) α estimates for quadropoly. The frequency for each α estimate is the same as the corresponding quality frequency, which is in Figure 3. Similar to duopoly, quadropoly α distributions show a stronger concentration below the normalized monopoly mean and are left-skewed, as in duopoly.

Estimations show striking differences between monopoly α distributions and the duopoly and quadropoly α distributions. Whereas preferences tend to exhibit diversity in monopoly, they are less diverse in duopoly, and becoming less so in quadropoly. Densities of estimated α's tend to vary quite a lot in monopoly, but a lot less so in duopoly and quadropoly. Moreover, estimated α distributions tend to be left-skewed and being more concentrated at the high end of the distribution.

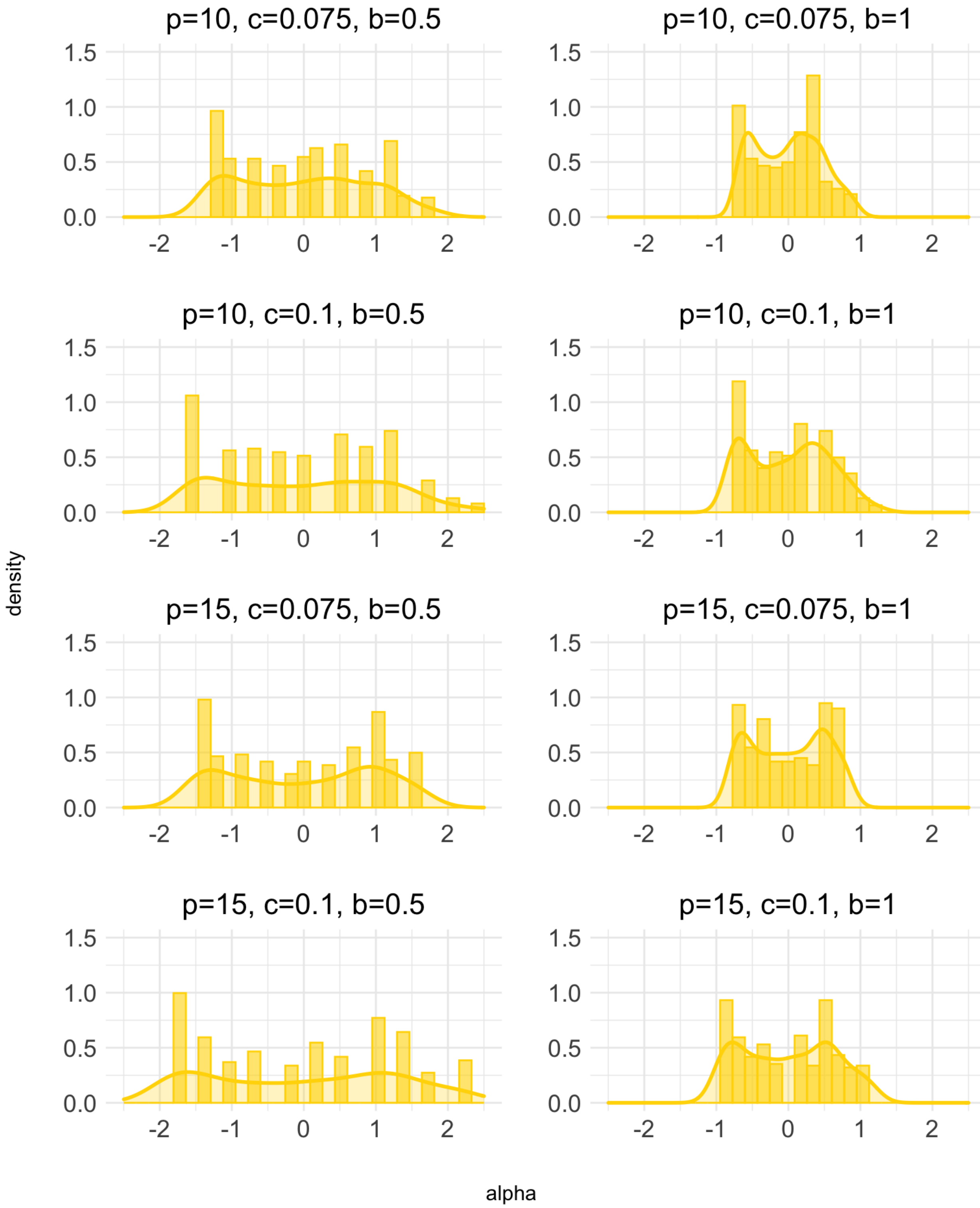

Figure 4: Histograms of normalized estimated α in each incentive configuration in monopoly

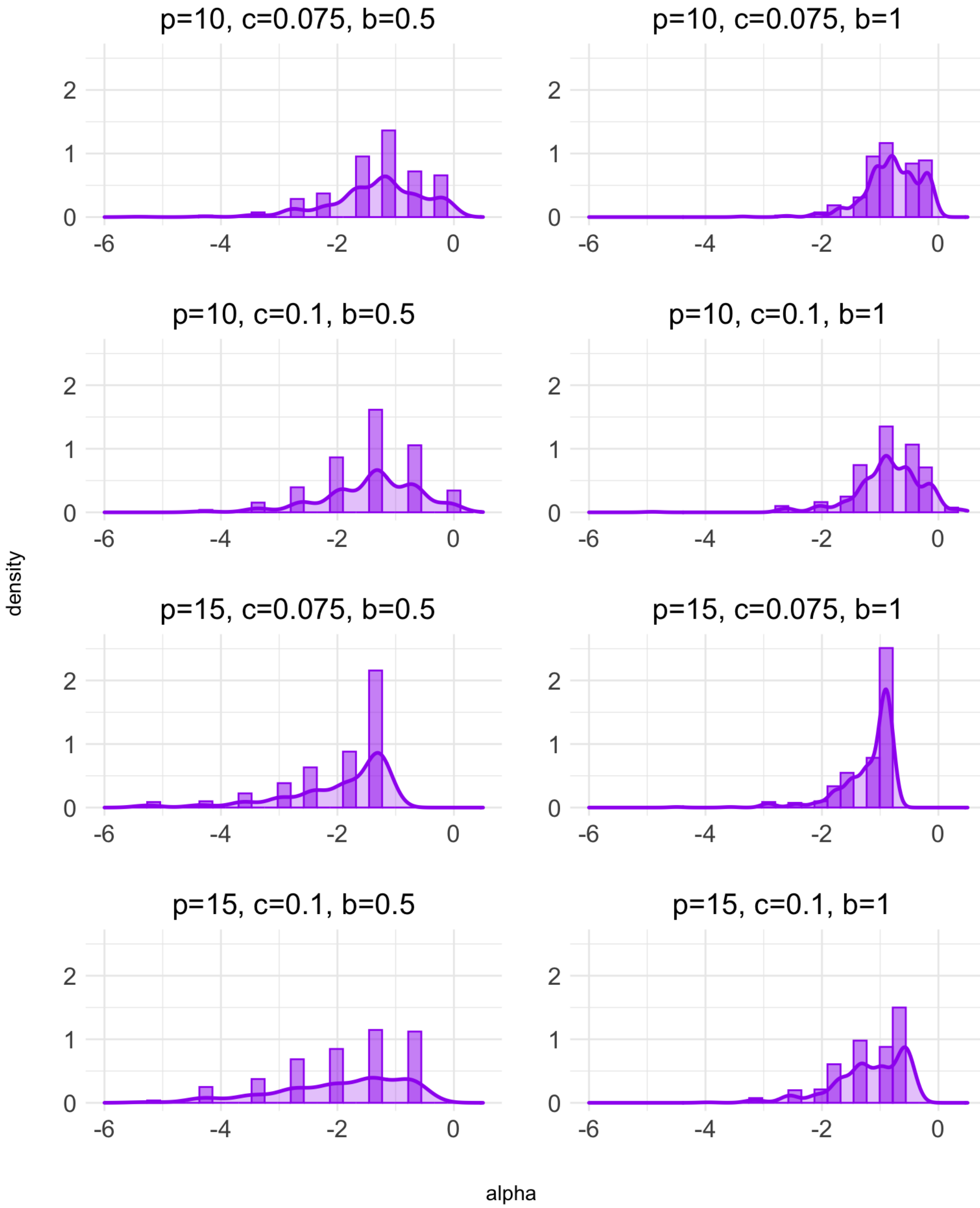

Figure 5: Histograms of normalized estimated α in each incentive configuration in duopoly

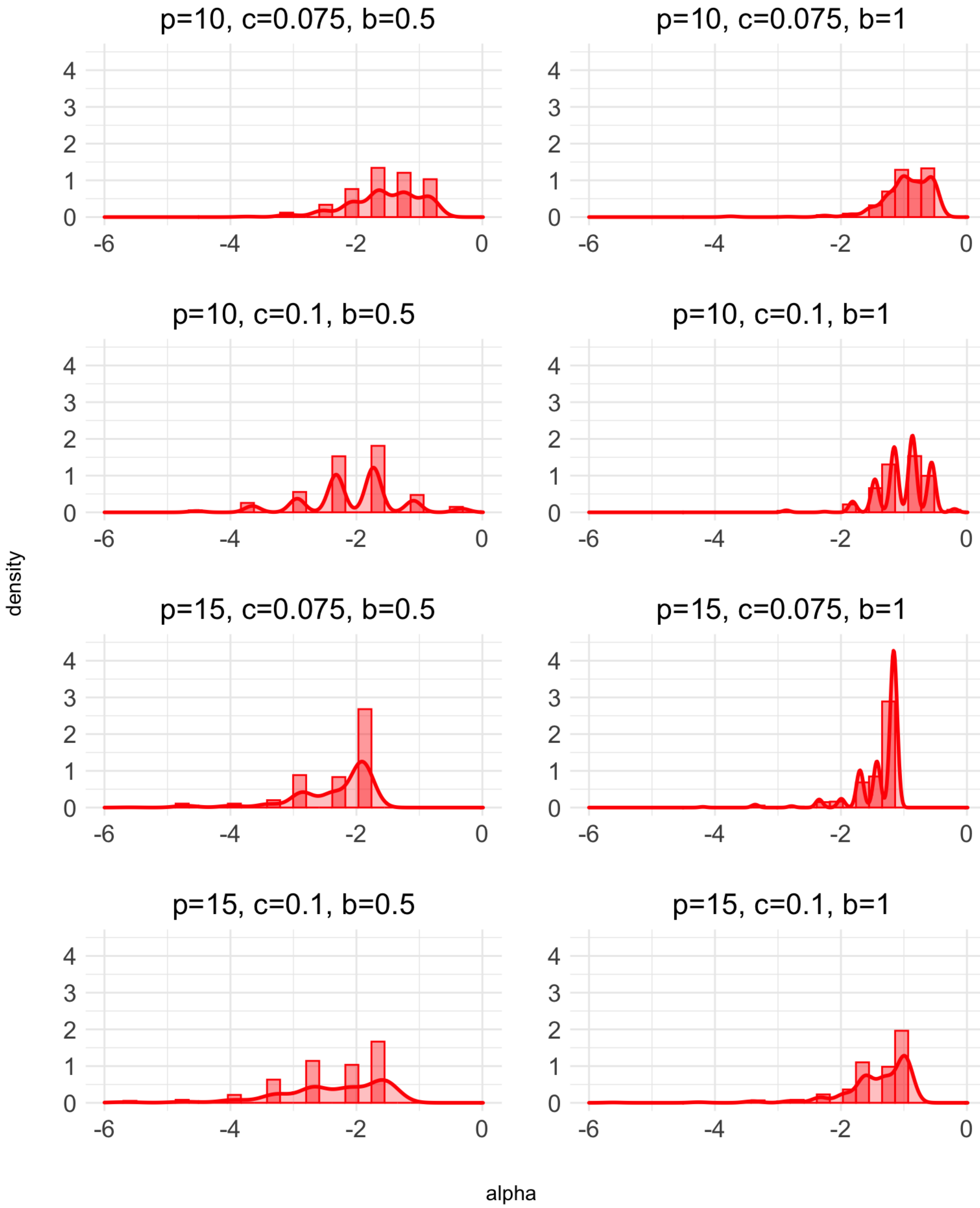

Figure 6: Histograms of normalized estimated α in each incentive configuration in quadropoly

4.4 Statistical tests on altruism distributions

We perform standard two-sample Kolmogorov-Smirnov (KS) tests on the (null) hypotheses that two estimated altruism distributions are drawn from the same continuous distribution.[12] The test statistic, KS distance, is the largest absolute difference between two empirical distribution functions; see, for example, Conover (1999). For two estimated α distributions, say $\widehat{F}_1$ and $\widehat{F}_2$, their KS distance is defined by $KS_{1,2} \equiv \sup_a |\widehat{F}_1(a) - \widehat{F}_2(a)|$. We have plotted the 24 actual estimated α distributions, not normalized at monopoly mean α, in Figure 7.

In each of the 8 incentive configurations, we compare 3 α-distribution pairs: i) monopoly versus duopoly (M-D), ii) monopoly versus quadropoly (M-Q), and iii) duopoly versus quadropoly (D-Q). Table 11 in Appendix B presents the KS distances for all 24 pairs; all the p-values are very small (reported to be less than 2.2×10^{-16} by the software R, so omitted in the table). Except in one incentive configuration $(p = 10, c = 0.1, b = 0.5)$, the KS distances are highest for M-Q, followed by M-D, and then D-Q. For incentive configuration $(p = 10, c = 0.1, b = 0.5)$, the only difference is that D-Q distance is higher than M-D distance. Hence, competition has an increasing effect on the reduction of altruim distribution. Because the p-values are so small, we reject the equality of the estimated α distributions in all comparisons.

Next, for each of the 3 markets, we consider α distributions from the 8 different incentive configurations. There are 28 pairs for comparisons in each market. Table 12 in Appendix B presents the KS distances for these distributions. There, pairs are labeled by the order in which they were presented in Section 3.1, on page 13; for instance, the label 1-2 denotes the incentive-configuration pair $(p = 10, c = 0.1, b = 1)$ and $(p = 10, c = 0.075, b = 1)$. The KS distances vary across different pairs. All p-values are much smaller than 0.01 (and have been omitted in the table); we reject the hypothesis that any pair of the estimated α distributions are identical.

[12] Whereas the KS test is on drawn samples, our α's are estimates. We did not manage to obtain the α's sampling distributions, so our KS tests would not take sampling errors into account. However, as we show below, the rejections are very strong, so it is unlikely that KS tests performed poorly.

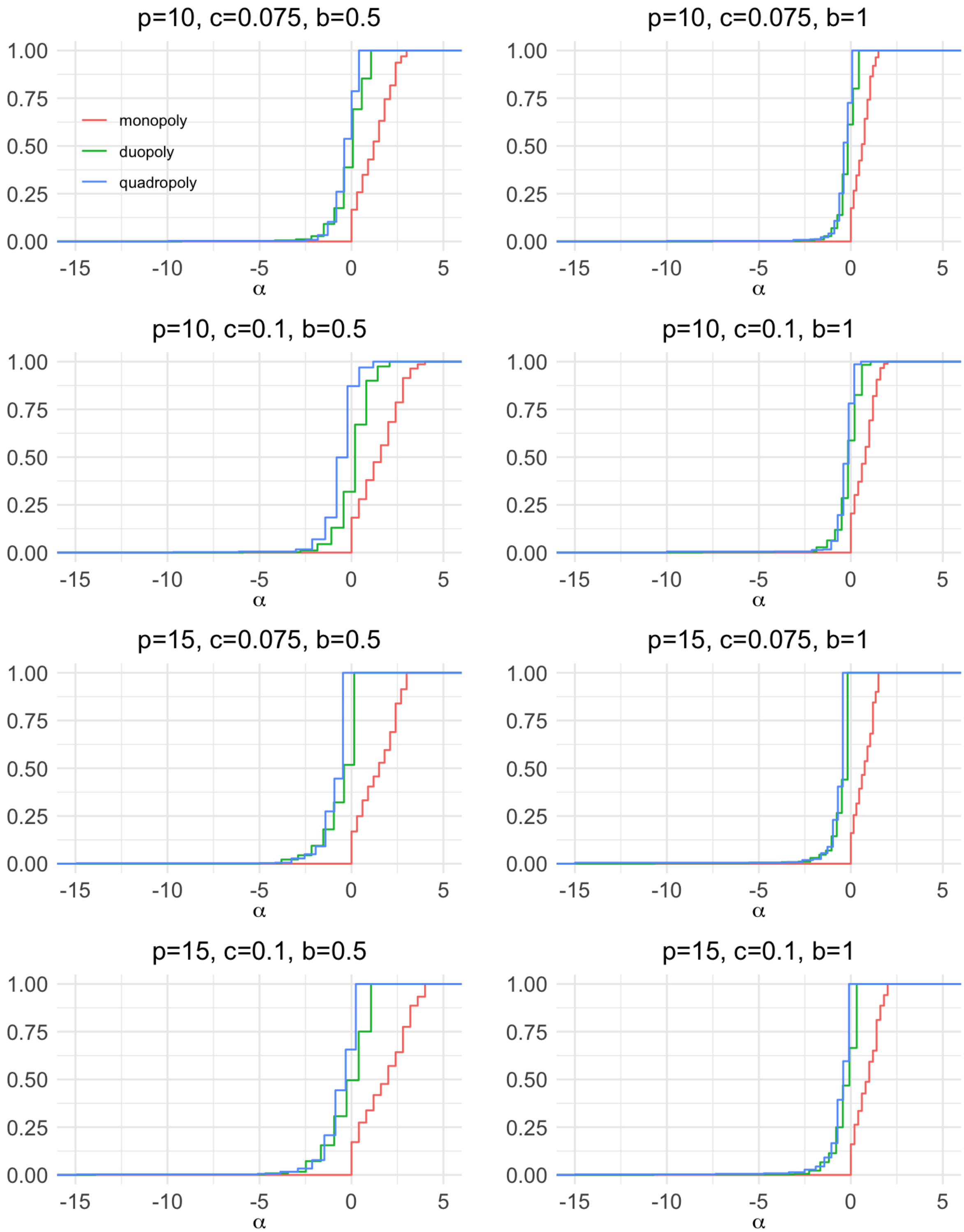

Figure 7: Distributions of estimated α in each market and in each incentive configuration.

Remark 4 (Bonferroni correction) *We test many related hypotheses. It is customary to adjust the p-values to account for multiple testings; see Czibor et al. (2019). We use the Bonferroni correction to adjust the p-values. Even after the correction, the majority of comparisons (104 out of 108) remain significant at 1%. Two comparisons of* α *distributions in incentive configurations under monopoly, however, become significant only at 5% after the correction:* $(p = 10, c = 0.1, b = 1)$ *vs.* $(p = 15, c = 0.075, b = 1)$ *and* $(p = 10, c = 0.1, b = 0.5)$ *vs.* $(p = 15, c = 0.075, b = 0.5)$*. For the comparison* $(p = 10, c = 0.075, b = 0.5)$ *vs.* $(p = 15, c = 0.075, b = 0.5)$ *under monopoly, we can still reject the same-distribution hypothesis at 10%. However, for* $(p = 15, c = 0.1, b = 0.5)$ *vs.*$(p = 10, c = 0.1, b = 0.5)$ *under monopoly, we cannot reject the identical-distribution even at 10% (the p-value is* 0.1206*).*

4.5 Counterfactual monopoly qualities from estimated duopoly and quadropoly altruism

Whereas Table 2 and Figures 1 to 3 report the outcomes, our structural estimation of α distributions in Subsection 4.2 can separately identify the effects (i) due to preferences change and (ii) due to market-incentive changes. However, results in Subsections 4.2 and 4.3 are obtained without explicit derivations of Bayes-Nash equilibria. One could not easily compute duopoly or quadropoly equilibrium quality distributions under the counterfactual that preference distributions remained unchanged at the monopoly configuration.

Instead, we perform counterfactual of the following sort. We use the estimated altruism distributions in an incentive configuration in duopoly or quadropoly to calculate the optimal qualities under monopoly. That is, we take α values and their frequencies from Tables 9 and 10 and feed them into the monopoly first-order condition (4) to calculate optimal qualities. The next two figures show the counterfactual histograms of monopoly qualities when α's are those identified in duopoly and quadropoly. In each counterfactual computation, we have limited the optimal qualities to be nonnegative. (Those estimated α in duopoly and quadropoly that are negative have been replaced by 0 to ensure a nonnegative optimal monopoly quality.) For ease of display, we round each counterfactual quality to its closest integer.

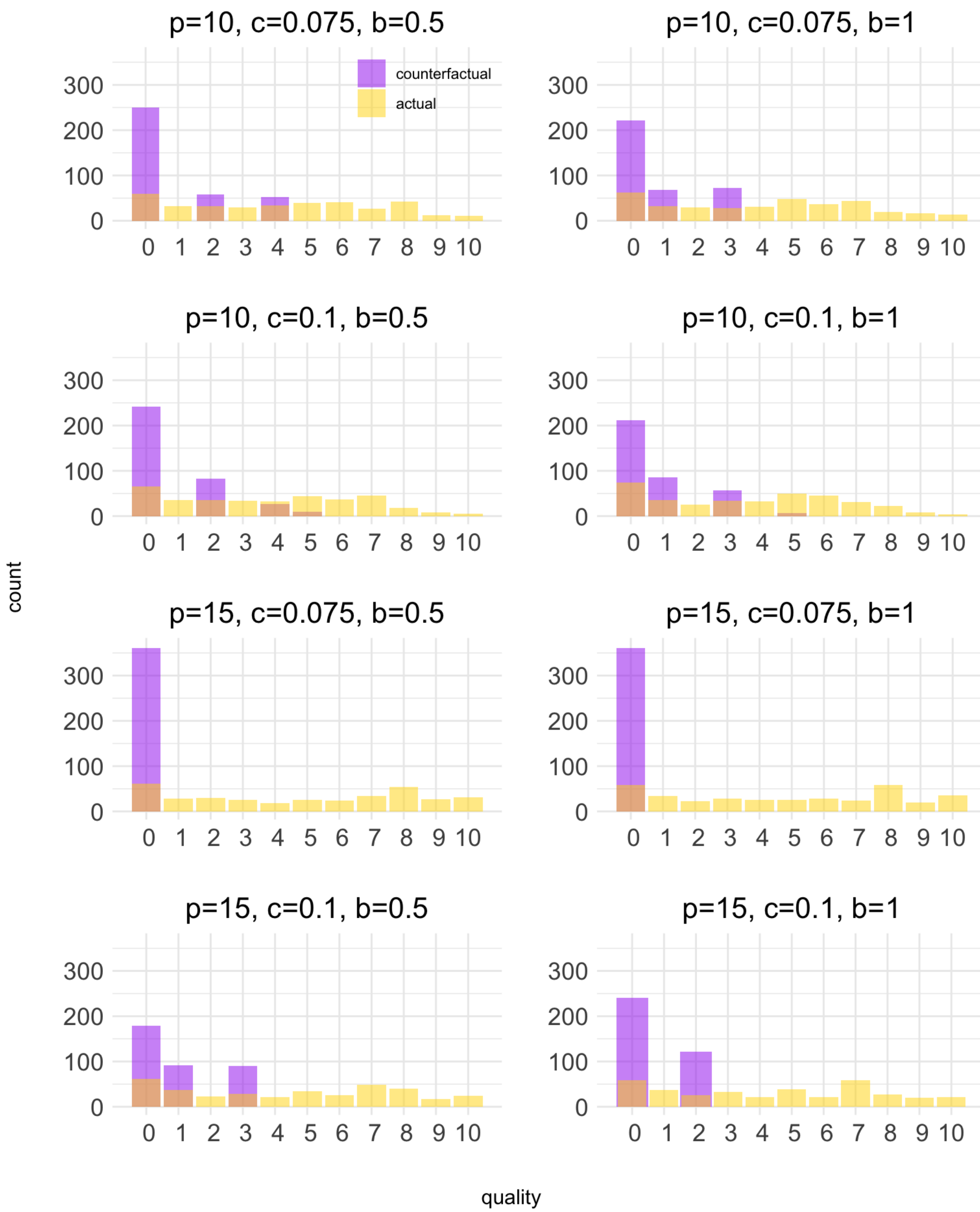

Figure 8: Counterfactual monopoly quality histogram from duopoly altruism α

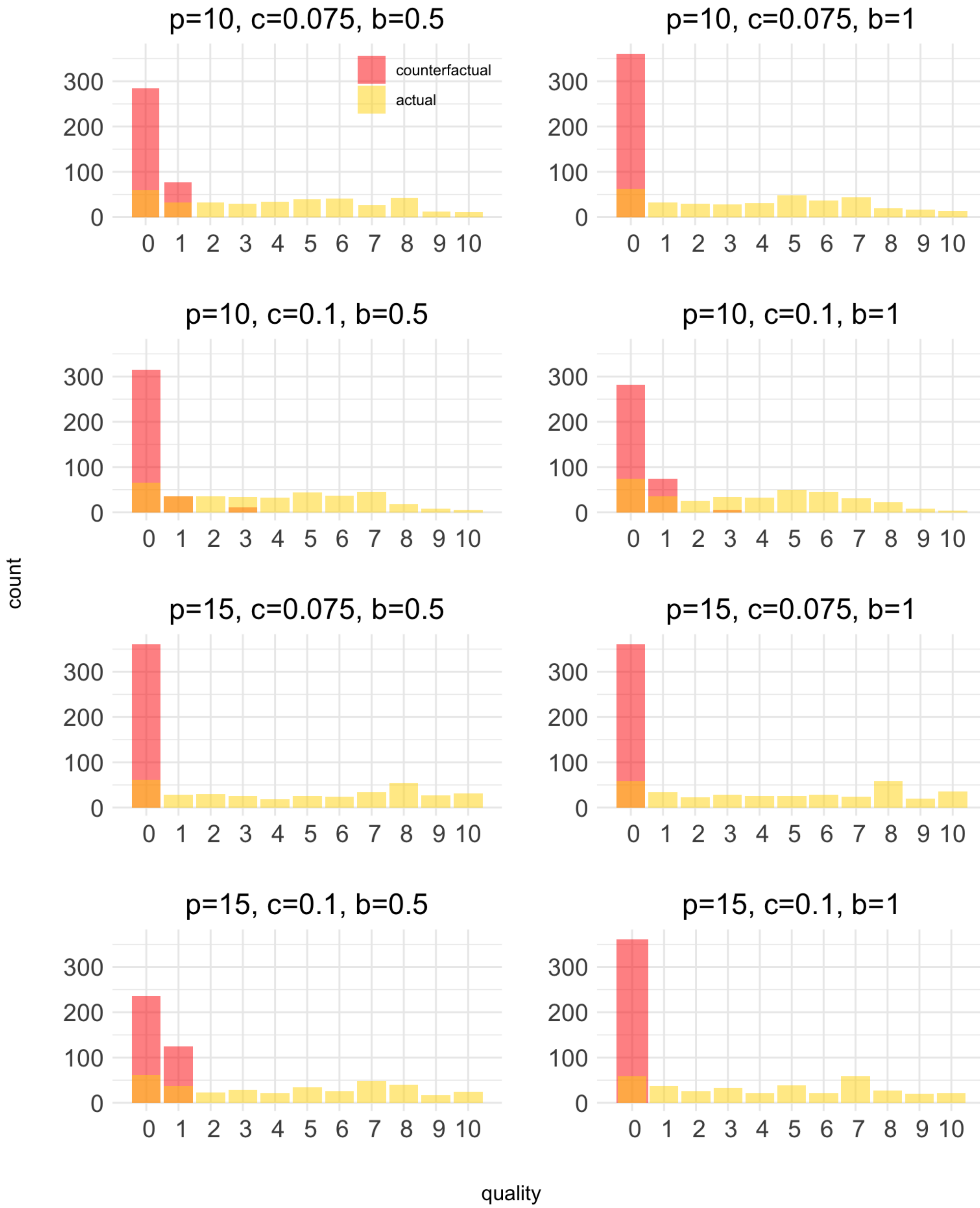

Figure 9: Counterfactual monopoly quality histogram from quadropoly altruism α

Differences between empirical monopoly qualities and counterfactual qualities are striking. Histograms in Figures 8 and 9 have no resemblance to those in the empirical quality distributions in Figure 1, which are shown for comparison as yellow bars. Counterfactual results provide more evidence that the altruism distribution changes according to market competition.

4.6 Discussions of theoretical model and structural estimation

Establishing the central thesis relies on a theoretical model on preferences, a game, and an experiment, followed by structural estimation of preferences via properties of Bayes-Nash equilibria. Results should be interpreted as a constellation of particular preferences and game-form definitions together with the GPV estimation adaptation; they should not be viewed in the isolation of a single component. The actual implementation requires certain assumptions. Perhaps most important is the one that the experimental outcome is sufficiently described by a symmetric Bayes-Nash equilibrium. Two issues naturally arise. Are Bayes-Nash equilibria sufficiently good for describing the experimental outcomes? Are there many, possibly asymmetric, equilibria?

The second issue is a common concern in structural estimation of equilibria in empirical industrial organization. The usual assumption in the extant literature is that the outcome is described by *one* equilibrium, and it is not critically important which one. As long as the outcome is driven by an equilibrium, the structural estimation results are not compromised. We have implicitly adopted this convention. However, we should concede that our game may have asymmetric equilibria, which generally are intractable.[13] However, in an anonymous game in which a player's rival is drawn randomly from a population, it is awkward to suppose that a fraction play one equilibrium strategy and another fraction play another.

Now, the first issue of whether subjects exhibit equilibrium behavior is more fundamental. We do concede

[13]Here is why asymmetric Bayes-Nash equilibria are impossible to handle. Suppose that there are 10 players. In one equilibrium, 5 players are using Strategy 1, and 5 players are using Strategy 2. Consider Player 1. He faces 4 players using Strategy 1, and 5 players using Strategy 2. And in an equilibrium, Player 1 must find it optimal to use Strategy 1. Now consider Player 6. He faces 5 players using Strategy 1, and 4 players using Strategy 2. And in equilibrium Player 6 must find it optimal to use Strategy 2. In general we end up with one integral equation for Strategy 1, and then another integral equation for Strategy 2, and they have to be solved simultaneously. And this is predicated on equal numbers of players using Strategy 1 and Strategy 2. Other combinations are feasible, so it is difficult to search for asymmetric equilibria. We are unaware of any paper that structurally estimates asymmetric equilibria.

that this is a maintained assumption; given our data and setup, it cannot be validated externally. Also, we were not prepared to allow subjects to practice-play Bayes-Nash equilibria. This is because any learning by subjects about equilibrium play would have contaminated the within-subject design. However, we should note that our experiment had not generated random or chaotic data. In any case, structural estimation of alternative solution concepts seems uncommon; if we had abandoned Bayes-Nash equilibria, we would be unable to resolve estimation problems.

The assumption that individuals are interested only in profits and patient benefits is maintained throughout. We would not be in a position to test if subjects would become spiteful, winning oriented, or fair-minded when they participate in duopoly or quadropoly because our design does minimize these contaminations. We have only told subjects very sparse outcome information. Subjects never have learned that they have been "disadvantaged" by the rival, that their qualities have been higher or lower than rivals', or that their choices turn out to be similar or very different from the population averages. We have limited subjects' ability to learn about each other by implementing a simultaneous-move game. Interaction between subjects and learning about the population are both impossible in our design. Every attempt has been made to ensure that a subject is playing against another randomly drawn subject.

5 Reduced-form analysis of experimental data

For reduced-form estimation, we begin with aggregated descriptive statistics.[14] A subject makes 8 quality choices in each market. Of these 8, four of them are made with one fixed incentive-configuration parameter. For example, under monopoly at $p = 10$, a subject chooses 4 qualities, whereas cost and patient-benefit parameters vary between low and high. We record the averages of these 4 qualities for each subject, and then we find the average of all 361 subjects (the average of a total of $1,444$ quality choices). In Table 5, the first entry 3.959 records the mean of subjects' average quality choices at $p = 10$, and 2.900 is the corresponding standard deviation. Across that row, when the price is set at 15, the higher value, the mean becomes 4.652, and the standard deviation becomes 3.327. The relative difference, 0.175, equals $(4.652 - 3.959)/3.959$. The

[14]Table 2 already describes the 24 quality means and standard deviations for the 3 markets and 8 incentive configurations, and Figures 1 to 3 show the quality histograms.

rest of Table 5 presents the quality-choice averages for each parameter in each market.[15]

From the first three rows with data entries in Table 5, average quality is higher in each market when the price is set at the higher value, but the relative difference declines as the market becomes more competitive. From the second set of data entries, average quality becomes lower when cost is set at the higher value, although the relative difference remains almost the same across markets. For patient benefits, quality averages exhibit a different pattern. For monopoly, a higher patient benefit results in a slightly lower average quality, whereas for duopoly and quadropoly, a high patient benefit results in slightly higher quality averages. But in all three markets, the relative difference seems very small.

Table 5: Descriptives on the variations in price, costs, and patient benefit

	Low parameter (N=1,444, per market)		High parameter (N=1,444, per market)		Relative
Parameter	Mean	st. dev.	Mean	st. dev.	difference
Price ($p = 10$; $p = 15$)					
Monopoly	3.959	2.900	4.652	3.327	0.175
Duopoly	7.442	1.573	8.595	1.625	0.155
Quadropoly	7.841	1.479	8.862	1.484	0.130
Cost ($c = 0.075$; $c = 0.1$)					
Monopoly	4.493	3.227	4.118	3.038	-0.083
Duopoly	8.380	1.660	7.657	1.662	-0.086
Quadropoly	8.704	1.489	8.000	1.564	-0.081
Patient benefit ($b = 0.5$; $b = 1$)					
Monopoly	4.323	3.150	4.287	3.128	-0.008
Duopoly	7.925	1.668	8.112	1.726	0.024
Quadropoly	8.310	1.523	8.393	1.608	0.010

Next we use ordinary least square regressions to study the effect of market competition and incentive-configurations:

$$q_i = \beta_0 + \beta_1 D + \beta_2 Q + \gamma_1 Price + \gamma_2 Cost + \gamma_3 Benefit + \psi \mathbf{X}_i + \varepsilon_i \tag{17}$$

where q_i, the dependent variable, is subject i's quality choice, and β_0 is the intercept. Experimental manipulations are defined by a set of dummies. Regarding monopoly as the reference market, we use the

[15] Table 5 aggregates the information in Table 2, which contains quality-choice means and standard deviations in each incentive-configuration-market constellation.

dummy variables D and Q to represent duopoly and quadropoly, respectively; a dummy is set to 1 when the quality on the left-hand side has been chosen under the corresponding market condition. The $Price$, $Cost$, and $Benefit$ variables are also dummies. The variable $Price$ takes the value of 1 when price p is equal to the high value of 15; it takes the value at 0 otherwise. Similarly, $Cost$ takes the value of 1 when $c = 0.1$, and $Benefit$ takes the value of 1 when patient benefit $b = 1$; otherwise, they are 0. Equation (17) includes a vector of additional control $\mathbf{X}_i$ of market orders (see Table 1) and session dummies, and finally ε_i is an error term. Model (1) in Table 6 presents the estimation results. In Model (2), we add market and incentive-configuration interaction terms.

From Table 6, quality is significantly higher in duopoly and quadropoly than monopoly, and the magnitudes are similar across models. Wald tests indicate a highly significant difference between Duopoly and Quadropoly ($p < 0.001$). For incentive configurations with a high price, a low cost, and a high patient benefits, qualities are significantly higher in Model (1). With interaction terms in Model (2), the effects of price and cost remain qualitatively similar but the magnitudes have declined. The average benefit effect becomes insignificant; this suggests that the patient-benefit effect may be market specific. Using Wald tests, we find that market effects are significantly larger than market-configuration effects (at $p < 0.001$).

From Models (1) and (2) results, more intense market competition has implemented higher equilibrium qualities. An interpretation of an unqualified success of competition (under regulated prices) on implementing higher qualities is misguided. Bayes-Nash equilibrium qualities depend on preferences, markets, and incentive configurations. Our structural estimation supports reduction in altruism, which generally reduces subjects' qualities in equilibrium. The scenario is more appropriately described as a tug of war—between altruism reduction and competition-incentive disciplinary powers. In our setting, competition-incentive powers have won over altruism reduction.

Table 6: Quality regressions

Model	(1)	(2)
Duopoly (D)	3.713***	3.545***
	(0.158)	(0.157)
Quadropoly (Q)	4.046***	3.987***
	(0.157)	(0.156)
High price (= 1 if $p = 15$)	0.955***	0.693***
	(0.029)	(0.050)
High cost (= 1 if $c = 0.1$)	-0.601***	-0.375***
	(0.024)	(0.046)
High benefit (= 1 if $b = 1$)	0.078***	-0.036
	(0.024)	(0.043)
Duopoly × High price		0.461***
		(0.066)
Quadropoly × High price		0.328***
		(0.061)
Duopoly × High cost		-0.348***
		(0.056)
Quadropoly × High cost		-0.328***
		(0.055)
Duopoly × High benefit		0.224***
		(0.056)
Quadropoly × High benefit		0.119**
		(0.055)
Market order and session dummies	Yes	Yes
Constant	3.971***	4.047***
	(0.400)	(0.399)
Observations	8,664	8,664
Subjects	361	361
R^2	0.445	0.447

Notes: OLS; robust standard errors clustered for subjects in brackets; *** for $p < 0.01$; ** for $p < 0.05$

6 Concluding remarks

Using data from an experiment in a health frame, we show that altruistic preferences are affected by markets and incentives. We model subjects' preferences through a linear utility function whose marginal rate of substitution is interpreted as the degree of altruism. Subjects play a simultaneous-move, incomplete-information game of duopoly and quadropoly. Using experimental data, we estimate the altruism distribution in each market-incentive environment. The estimation results show that subjects are less altruistic when they have to compete against each other.

Although our conclusion is that altruism has changed, we have maintained certain assumptions, both in the theoretical model and in the experiment. The structural model does require some consistency in preferences between different markets and incentive configurations. So to speak, we can estimate changing preferences only if those changes are not so drastic. We narrow down our study to one altruism parameter. The theoretical model, the identification of Bayes-Nash equilibria, and the structural estimation of preference parameters all must fit together to yield our results.

Economic institutions may shape preferences just as climate, cultural-historical events, physiology, and genetics. Observations of financial incentives crowding out are decomposed into behavioral and preference changes. This paper offers a deeper understanding of the forces underlying markets and incentives.

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Appendix A Materials for the experiment

A.1 Instructions

You are taking part in an economic decision-making experiment. Please carefully read the instructions. It is very important that you do not speak with other participants for the duration of the experiment. If you break these rules, you could be excluded from the experiment and not receive any payment. If you do not understand something, please take another look at the instructions. If you still have questions, please raise your hand. We will come to you at your cubicle and answer your questions in private.

You can earn money in the course of the experiment. The amount of your earnings depends on your decisions and decisions made by other participants. At no time will you be told the names of the other participants. They will also not at any time be informed about your identity.

For showing up you will receive a fee of EUR 4.00.

All monetary amounts in this experiment are expressed in Taler, whereby the following applies: Taler 100 = EUR 1.

At the end of the experiment, the amount of money you earned will be paid to you in cash. Your decisions are made on the computer screen present in your cubicle. All data and answers will be evaluated anonymously. You were asked to draw your own personal cubicle number in order to maintain anonymity.

The experiment will last around 60 minutes and consists of three parts. Before each of the three parts you will receive detailed instructions and be asked to answer control questions pertaining to these instructions. Please note: Neither your decisions in the first part nor in the second part of the experiment have an influence on the other parts of the experiment.

We will ask you to answer a few questions at the end of the experiment. You will receive an additional payment for answering this questionnaire.

First part of the Experiment. In the first part of experiment, you will take on the role of a physician and make decisions about the treatment of various patients. In total, you will determine the quality of care that you would like provide for eight different types of patients. For each of these patients you can choose quality of 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10.

The demand for medical care by the various patient types is determined only after you have made your decisions about the quality of care for all eight types.

[Duopoly: You are randomly matched with another participant. This participant also decides in the role of a physician. Also this physician determines the quality for the same eight types of patients. The matching with this participants remains throughout the entire second part of the experiment. You and the other physician chose the quality simultaneously and independently from each other.]

[Quadropoly: You are randomly matched with three other participants. These participants also decide in the role of a physicians. Also these physicians determine the quality for the same eight types of patients. The matching with these participants remains throughout the entire third part of the experiment. You and the other physicians chose the quality simultaneously and independently from each other.]

In total, 100 patients of each type demand medical care. It will only be determined after you have made your decisions about the quality of care for all eight types how many of the 100 patients of each type wish to seek treatment from you.

[Duopoly: Only after you and the other physician, you are matched with, decided upon the quality of medical treatment for the eight patients, it is determined how many of the 100 patients seek treatment from you and the other physician.]

[Quadropoly: Only after you and the others physicians, you are matched with, decided upon the quality of medical treatment for the eight patients, it is determined how many of the 100 patients seek treatment from you and the other physicians.]

Earnings. For each patient who seeks medical care from you, you receive a lump sum that is independent of the quality of care you have selected. You incur costs with your selection of the quality of care. These costs depend on the quality level you choose and can vary between the different patient types. Your earnings for each patient type are as follows:

$$\text{Earnings} = (\text{Lumpsum-Costs}) \times \text{Number of patients who seek medical care from you}$$

(when read: your earnings are equal to the difference between the lump sum and the costs that arise from the quality of care you have chosen, multiplied by the number of patients who seek treatment from you.)

With the quality of care you choose, you determine not only your own earnings, but also the utility enjoyed by the patient. The amount of the lump sum, your costs, your earnings, and the patient's utility will be displayed on your screen (as illustrated in Subsection A.3) for each patient type.

Before you choose the quality of care for each patient type, you have the opportunity to click on the "calculator" button and thereby calculate patients' potential demand for treatment (as illustrated in Subsection A.3). You can enter the quality you would like to provide as many times as you want. Clicking on the "calculate" button provides you with information about the number of patients who would seek care given the quality level you entered. In addition, you receive information about the resulting earnings and patient utility. You define the quality of care that you wish to provide by entering that quality in the field "your decision" and confirming this entry with "OK."

Payment. After the conclusion of the experiment, one of the 8 decisions will be randomly chosen to function as the relevant round for determining your payment for this part of the experiment. The earnings from this randomly-chosen round will be converted into Euro at the end of the experiment and paid out to you in cash. There are no participants present in the lab who take on the role of patients. An actual patient will benefit from the patient utility resulting from the quality of care you selected in the randomly-chosen round: A monetary value equaling the patient utility derived from your decision, multiplied by the number of patients who seek treatment from you, will be transferred to Christoffel Blindenmission Deutschland e.V., 64625 Bensheim. This organization will use the funds to enable the treatment of patients suffering from cataracts, a serious eye condition.

Control questions. Before proceeding to the decisions in the experiment, we would like to ask you to answer several control questions. These control questions should make it easier for you become acquainted with the decision-making situation. If you have questions about this, please raise your hand. The first part of the experiment will begin after all participants have correctly answered the control questions.

Payment Procedure. In order to ensure that payments to the participants and the transfer of the monetary donation to Christoffel Blindenmission Deutschland e.V. are carried out correctly, an overseer will be randomly chosen after the third part of the experiment. The overseer receives a fee of Euro 5 in addition to his or her regular payment from the experiment. The overseer will affirm that the transfer to Christoffel Blindenmission is correctly carried out by the financial administration of the University of Cologne. For the transfer to Christoffel Blindenmission, the overseer will fill out a payment order to Christoffel Blindenmission with the amount, in Euro, that corresponds to the patient utility realized in the randomly-selected round. The financial administration of the University of Cologne will then execute payment of the donation to Christoffel Blindenmission using funds allocated for this experiment. The form will be placed in a stamped envelope addressed to the financial administration of the University of Cologne. The overseer and the experimenter will jointly deposit this envelope in the nearest mailbox.

The overseer will confirm by signing a form that he or she properly carried out the assigned tasks, as described above. A copy of this form, as well as a copy of the confirmation from Christoffel Blindenmission that the donation was received, can be requested by all participants from the office of the Seminar of Personnel Economics and Human Resource Management. The copies will be sent by e-mail.

A.2 Control questions of the experiment

Comprehension questions

[The comprehension questions are presented for the market order Monopoly-Duopoly-Quadropoly. Question that are the same irrespective of the market setting are marked with an asterisk (*).]

Monopoly

1. In the first part of the experiment, you decide in the role of a ____________ about the treatment of ____________ .(*)

2. For how many different patient types, do you decide on quality of treatment ____________

3. How many patients of each type demand medical services in total? ____________

4. How many physicians decide on the quality of medical services beside you in a market? ____________

5. Is the following statement true or false? *"Your quality choice for a patient does not only determine your profit but also the patient's benefit."* (*)

   ⊡ True

   ⊡ False

   To answer the following two questions, please consider the examples on your computer screen.

6. Please consider **Example A** on your computer screen. Please assume that you would choose **a quality of 1** for patients of this type. For one patient, what is

   a. your capitation? ____________

   b. your costs? ____________

   c. your profit? ____________

   d. the patient's benefit? ____________

7. Again, please consider **Example A** on your computer screen. Please assume, that you would choose **a quality of 4** for the patients of this type (*Hint: To answer the questions below, please use the calculator on your computer screen.*).

   a. What is the patient demand for your treatment quality? ____________

   b. What is your profit? ____________

   c. What is the patient's benefit? ____________

8. Now, please consider **Example B** on your computer screen. Please assume, that you would choose **a quality of 7** for patients of this type. For one patient, what is

   a. your capitation? ____________

b. your costs? ____________

c. your profit? ____________

d. the patient's benefit? ____________

9. Again, please consider **Example B** on your computer screen. Please assume, that you would choose **a quality of 5** for the patients of this type (*Hint: To answer the questions below, please use the calculator on your computer screen.*).

   a. What is the patient demand for your treatment quality? ____________

   b. What is your profit? ____________

   c. What is the patient's benefit? ____________

10. Which of the following statements is true? (*)

   ⊡ Your quality choice for a patient type determines the number of patients of this type who demand your treatment quality. For those patients, who demand your treatment, the quality choice determines the patient benefit. In addition, your quality choice determines your profit for the patient type.

   ⊡ Your quality choice for a patient type determines the number of patients of that type who demand your treatment quality. While your quality choice has no influence on the patient benefit it determines your profit.

   ⊡ Your quality choice for a patient type does not determine the number of patients of that type who demand your treatment quality. Your quality choice has no influence on the patient benefit and only determines your profit.

   ⊡ None.

11. Please complete the following sentence!

After the completion of the experiment, it will be determined ____________, which of your ______ decisions from this part of the experiment is relevant for determining your payment and the patient's benefit. (*)

Duopoly

1. For how many different patient types, do you decide on quality of treatment ____________

2. How many patients of each type demand medical services in total? ____________

3. How many physicians decide on the quality of medical services beside you in a market? ____________

   To answer the following two questions, please consider the examples on your computer screen.

4. Please consider **Example A** on your computer screen. Please assume that you would choose **a quality of 1** for patients of this type. For one patient, what is

   a. your capitation? ____________

   b. your costs? ____________

   c. your profit? ____________

   d. the patient's benefit? ____________

5. Again, please consider **Example A** on your computer screen. Please assume, that you would choose **a quality of 4** for the patients of this type. The other physician would choose **a quality of 3** (*Hint: To answer the questions below, please use the calculator on your computer screen.*).

   a. What is the patient demand for your treatment quality? ____________

   b. What is the patient demand for the other physician's treatment quality? ____________

   c. What is your profit? ____________

   d. What is the other physician's profit? ____________

   e. What is the patient's benefit resulting from your quality decision? ____________

   e. What is the patient's benefit resulting from the other physician's quality decision? ____________

6. Now, please consider **Example B** on your computer screen. Please assume, that you would choose **a quality of 7** for patients of this type. For one patient, what is

a. your capitation? ____________

b. your costs? ____________

c. your profit? ____________

d. the patient's benefit? ____________

7. Again, please consider **Example B** on your computer screen. Please assume, that you would choose **a quality of 5** for the patients of this type. The other physician would choose **a quality of 6** (*Hint: To answer the questions below, please use the calculator on your computer screen.*).

   a. What is the patient demand for your treatment quality? ____________

   b. What is the patient demand for the other physician's treatment quality? ____________

   c. What is your profit? ____________

   d. What is the other physician's profit? ____________

   e. What is the patient's benefit resulting from your quality decision? ____________

   e. What is the patient's benefit resulting from the other physician's quality decision? ____________

Quadropoly

1. For how many different patient types, do you decide on quality of treatment ____________

2. How many patients of each type demand medical services in total? ____________

3. How many physicians decide on the quality of medical services beside you in a market? ____________

   To answer the following two questions, please consider the examples on your computer screen.

4. Please consider **Example A** on your computer screen. Please assume that you would choose **a quality of 1** for patients of this type. For one patient, what is

   a. your capitation? ____________

   b. your costs? ____________

c. your profit? ____________

d. the patient's benefit? ____________

5. Again, please consider **Example A** on your computer screen. Please assume, that you would choose **a quality of 4** for the patients of this type. The other physicians would choose **a quality of 3** (*Hint: To answer the questions below, please use the calculator on your computer screen.*).

   a. What is the patient demand for your treatment quality? ____________

   b. What is the patient demand for the second physician's treatment quality? ____________

   c. What is the patient demand for the third physician's treatment quality? ____________

   d. What is the patient demand for the fourth physician's treatment quality? ____________

   e. What is your profit? ____________

   f. What is the second physician's profit? ____________

   g. What is the third physician's profit? ____________

   h. What is the fourth physician's profit? ____________

   i. What is the patient's benefit resulting from your quality decision? ____________

   j. What is the patient's benefit resulting from the second physician's quality decision? ____________

   k. What is the patient's benefit resulting from the third physician's quality decision? ____________

   l. What is the patient's benefit resulting from the fourth physician's quality decision? ____________

6. Now, please consider **Example B** on your computer screen. Please assume, that you would choose **a quality of 7** for patients of this type. For one patient, what is

   a. your capitation? ____________

   b. your costs? ____________

   c. your profit? ____________

   d. the patient's benefit? ____________

7. Again, please consider **Example B** on your computer screen. Please assume, that you would choose **a quality of 5** for the patients of this type. The second and the third physician would choose **a quality of 6**. The fourth physician would choose **a quality of 4**. (*Hint: To answer the questions below, please use the calculator on your computer screen.*).

   a. What is the patient demand for your treatment quality? ____________

   b. What is the patient demand for the second physician's treatment quality? ____________

   c. What is the patient demand for the third physician's treatment quality? ____________

   d. What is the patient demand for the fourth physician's treatment quality? ____________

   e. What is your profit? ____________

   f. What is the second physician's profit? ____________

   g. What is the third physician's profit? ____________

   h. What is the fourth physician's profit? ____________

   i. What is the patient's benefit resulting from your quality decision? ____________

   j. What is the patient's benefit resulting from the second physician's quality decision? ____________

   k. What is the patient's benefit resulting from the third physician's quality decision? ____________

   l. What is the patient's benefit resulting from the fourth physician's quality decision? ____________

A.3 Screenshots and experiment parameters

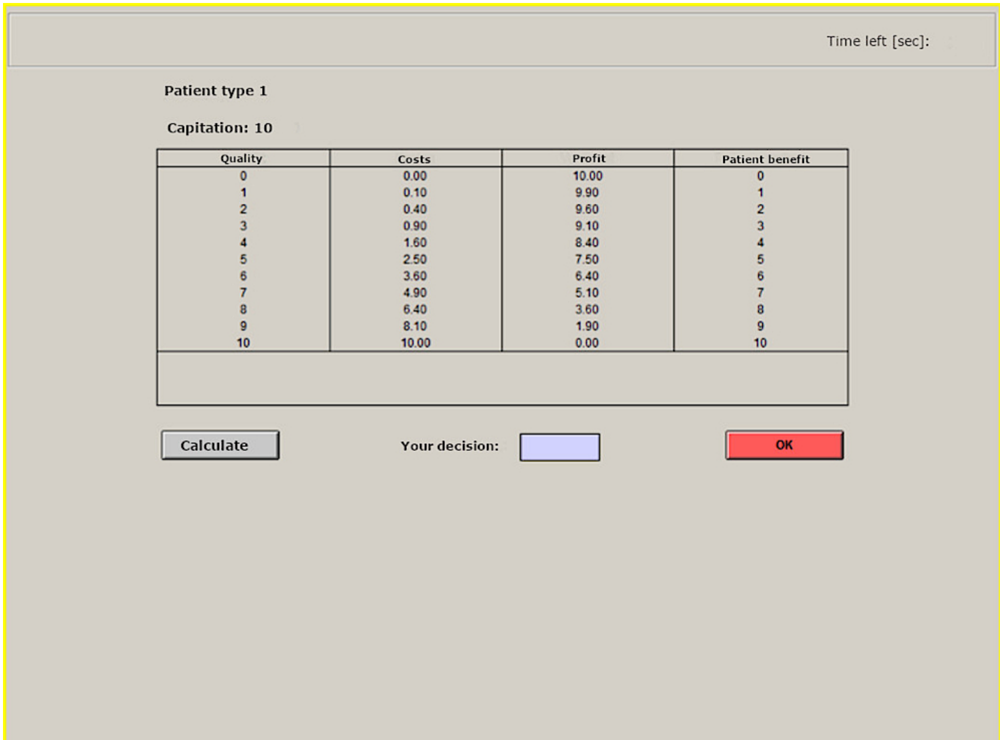


Figure 10: Decision screenshot

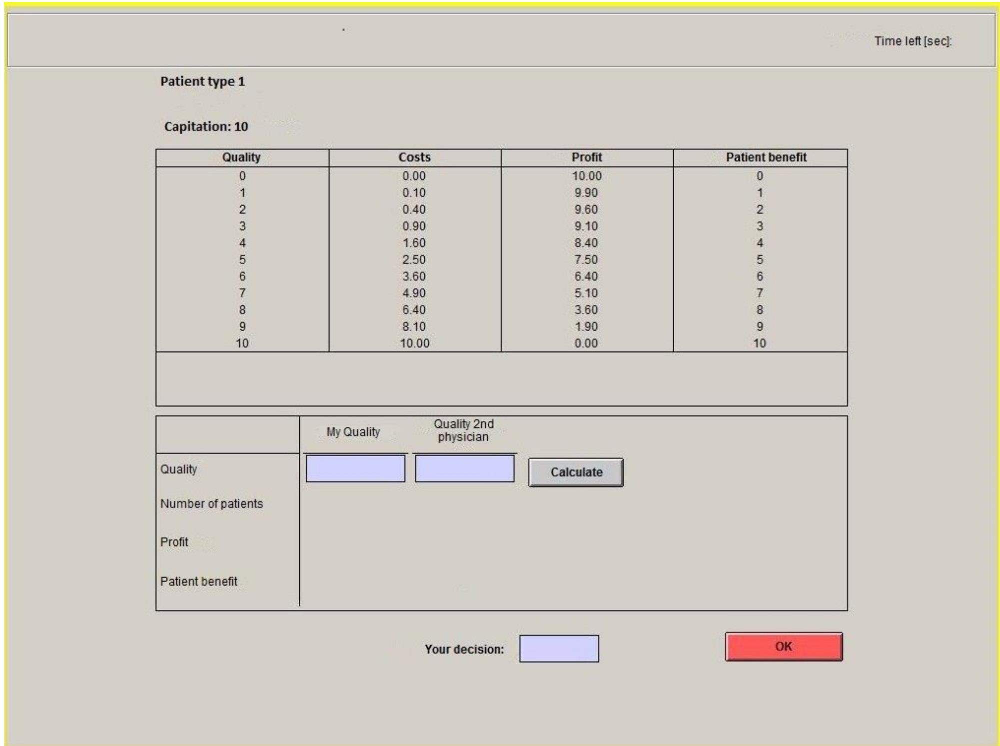


Figure 11: Duopoly calculator screenshot

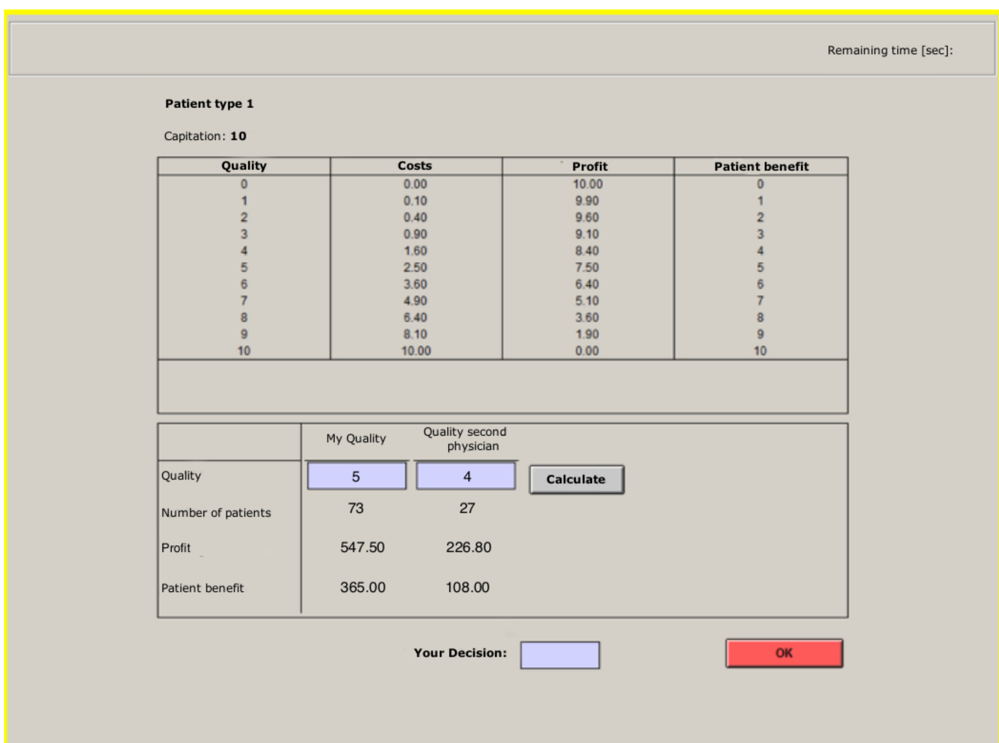
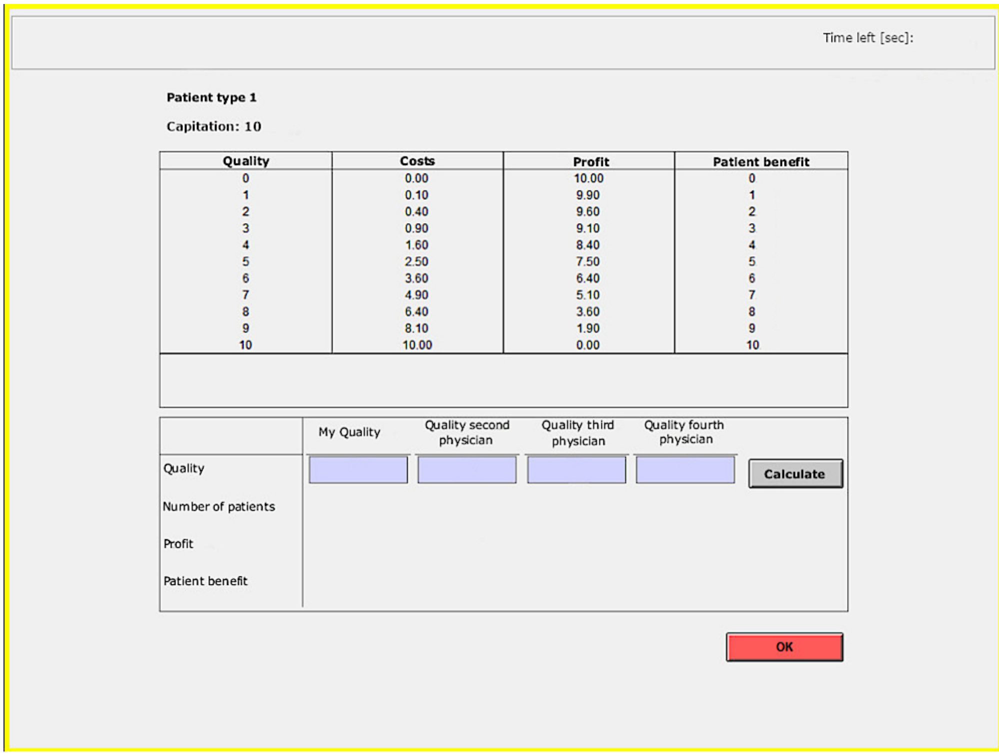


Figure 12: Duopoly calculator screenshot with qualities inputted



Quality	Costs	Profit	Patient benefit
0	0.00	10.00	0
1	0.10	9.90	1
2	0.40	9.60	2
3	0.90	9.10	3
4	1.60	8.40	4
5	2.50	7.50	5
6	3.60	6.40	6
7	4.90	5.10	7
8	6.40	3.60	8
9	8.10	1.90	9
10	10.00	0.00	10

Figure 13: Quadropoly calculator screenshot

Table 7: Experiment parameters

	Quality, q										
	0	1	2	3	4	5	6	7	8	9	10
Incentive configuration 1 ($p = 10$, $c = 0.1$, $b = 1$)											
Capitation, p	10	10	10	10	10	10	10	10	10	10	10
Cost, $c(q)$	0	0.1	0.4	0.9	1.6	2.5	3.6	4.9	6.4	8.1	10
Profit, $p - c(q)$	10	9.9	9.6	9.1	8.4	7.5	6.4	5.1	3.6	1.9	0
Patient benefit, q	0	1	2	3	4	5	6	7	8	9	10
Incentive configuration 2 ($p = 10$, $c = 0.075$, $b = 1$)											
Capitation, p	10	10	10	10	10	10	10	10	10	10	10
Cost, $c(q)$	0	0.075	0.3	0.675	1.2	1.875	2.7	3.675	4.8	6.075	7.5
Profit, $p - c(q)$	10	9.925	9.7	9.325	8.8	8.125	7.3	6.325	5.2	3.925	2.5
Patient benefit, q	0	1	2	3	4	5	6	7	8	9	10
Incentive configuration 3 ($p = 15$, $c = 0.1$, $b = 0.5$)											
Capitation, p	15	15	15	15	15	15	15	15	15	15	15
Cost, $c(q)$	0	0.1	0.4	0.9	1.6	2.5	3.6	4.9	6.4	8.1	10
Profit, $p - c(q)$	15	14.9	14.6	14.1	13.4	12.5	11.4	10.1	8.6	6.9	5
Patient benefit, q	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
Incentive configuration 4 ($p = 15$, $c = 0.1$, $b = 1$)											
Capitation, p	15	15	15	15	15	15	15	15	15	15	15
Cost, $c(q)$	0	0.1	0.4	0.9	1.6	2.5	3.6	4.9	6.4	8.1	10
Profit, $p - c(q)$	15	14.9	14.6	14.1	13.4	12.5	11.4	10.1	8.6	6.9	5
Patient benefit, q	0	1	2	3	4	5	6	7	8	9	10
Incentive configuration 5 ($p = 10$, $c = 0.1$, $b = 0.5$)											
Capitation, p	10	10	10	10	10	10	10	10	10	10	10
Cost, $c(q)$	0	0.1	0.4	0.9	1.6	2.5	3.6	4.9	6.4	8.1	10
Profit, $p - c(q)$	10	9.9	9.6	9.1	8.4	7.5	6.4	5.1	3.6	1.9	0
Patient benefit, q	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
Incentive configuration 6 ($p = 10$, $c = 0.075$, $b = 0.5$)											
Capitation, p	10	10	10	10	10	10	10	10	10	10	10
Cost, $c(q)$	0	0.075	0.3	0.675	1.2	1.875	2.7	3.675	4.8	6.075	7.5
Profit, $p - c(q)$	10	9.925	9.7	9.325	8.8	8.125	7.3	6.325	5.2	3.925	2.5
Patient benefit, q	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
Incentive configuration 7 ($p = 15$, $c = 0.075$, $b = 1$)											
Capitation, p	15	15	15	15	15	15	15	15	15	15	15
Cost, $c(q)$	0	0.075	0.3	0.675	1.2	1.875	2.7	3.675	4.8	6.075	7.5
Profit, $p - c(q)$	15	14.925	14.7	14.325	13.8	13.125	12.3	11.325	10.2	8.925	7.5
Patient benefit, q	0	1	2	3	4	5	6	7	8	9	10
Incentive configuration 8 ($p = 15$, $c = 0.075$, $b = 0.5$)											
Capitation, p	15	15	15	15	15	15	15	15	15	15	15
Cost, $c(q)$	0	0.075	0.3	0.675	1.2	1.875	2.7	3.675	4.8	6.075	7.5
Profit, $p - c(q)$	15	14.925	14.7	14.325	13.8	13.125	12.3	11.325	10.2	8.925	7.5
Patient benefit, q	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5

Appendix B: Tables of α estimates, and KS-distances

Table 8: Estimated monopoly α values, normalized at mean

$q=0$	$q=1$	$q=2$	$q=3$	$q=4$	$q=5$	$q=6$	$q=7$	$q=8$	$q=9$	$q=10$
($p=10$, $c=0.075$, $b=0.5$)										
-1.252	-0.952	-0.652	-0.352	-0.052	0.248	0.548	0.848	1.148	1.448	1.748
($p=10$, $c=0.075$, $b=1$)										
-0.622	-0.472	-0.322	-0.172	-0.022	0.128	0.278	0.428	0.578	0.728	0.878
($p=10$, $c=0.1$, $b=0.5$)										
-1.515	-1.115	-0.715	-0.315	0.085	0.485	0.885	1.285	1.685	2.085	2.485
($p=10$, $c=0.1$, $b=1$)										
-0.746	-0.546	-0.346	-0.146	0.054	0.254	0.454	0.654	0.854	1.054	1.254
($p=15$, $c=0.075$, $b=0.5$)										
-1.446	-1.146	-0.846	-0.546	-0.246	0.054	0.354	0.654	0.954	1.254	1.554
($p=15$, $c=0.075$, $b=1$)										
-0.725	-0.575	-0.425	-0.275	-0.125	0.025	0.175	0.325	0.475	0.625	0.775
($p=15$, $c=0.1$, $b=0.5$)										
-1.805	-1.405	-1.005	-0.605	-0.205	0.195	0.595	0.995	1.395	1.795	2.195
($p=15$, $c=0.1$, $b=1$)										
-0.889	-0.689	-0.489	-0.289	-0.089	0.111	0.311	0.511	0.711	0.911	1.111

Table 9: Estimated duopoly α values, normalized at monopoly mean

$q=0$	$q=1$	$q=2$	$q=3$	$q=4$	$q=5$	$q=6$	$q=7$	$q=8$	$q=9$	$q=10$
($p=10$, $c=0.075$, $b=0.5$)										
-10.486	-	-5.422	-4.272	-3.430	-2.758	-2.186	-1.668	-1.177	-0.689	-0.187
($p=10$, $c=0.075$, $b=1$)										
-8.148	-	-3.359	-2.603	-2.079	-1.682	-1.359	-1.071	-0.792	-0.506	-0.187
($p=10$, $c=0.1$, $b=0.5$)										
-	-7.4	-	-4.289	-3.364	-2.608	-1.942	-1.321	-0.710	-0.088	0.559
($p=10$, $c=0.1$, $b=1$)										
-8.824	-4.912	-	-2.613	-2.038	-1.607	-1.244	-0.900	-0.542	-0.141	0.332
($p=15$, $c=0.075$, $b=0.5$)										
-	-	-	-6.430	-5.252	-4.349	-3.613	-2.979	-2.403	-1.851	-1.296
($p=15$, $c=0.075$, $b=1$)										
-11.376	-6.272	-4.496	-3.569	-2.923	-2.443	-2.079	-1.772	-1.489	-1.213	-0.900
($p=15$, $c=0.1$, $b=0.5$)										
-15.714	-	-	-6.486	-5.255	-4.284	-3.468	-2.744	-2.071	-1.412	-0.741
($p=15$, $c=0.1$, $b=1$)										
-11.589	-	-	-3.956	-3.156	-2.551	-2.082	-1.688	-1.326	-0.967	-0.568

Table 10: Estimated quadropoly α values, normalized at monopoly mean

$q=0$	$q=1$	$q=2$	$q=3$	$q=4$	$q=5$	$q=6$	$q=7$	$q=8$	$q=9$	$q=10$
($p=10$, $c=0.075$, $b=0.5$)										
-11.194	-	-	-	-3.733	-3.079	-2.540	-2.073	-1.648	-1.245	-0.845
($p=10$, $c=0.075$, $b=1$)										
-10.619	-	-3.753	-2.838	-2.258	-1.843	-1.521	-1.253	-1.015	-0.788	-0.550
($p=10$, $c=0.1$, $b=0.5$)										
-21.505	-11.209	-7.642	-	-4.539	-3.651	-2.941	-2.322	-1.730	-1.095	-0.331
($p=10$, $c=0.1$, $b=1$)										
-10.742	-	-	-2.866	-2.258	-1.815	-1.460	-1.154	-0.864	-0.560	-0.197
($p=15$, $c=0.075$, $b=0.5$)										
-16.391	-	-	-	-5.598	-4.707	-3.992	-3.390	-2.860	-2.374	-1.908
($p=15$, $c=0.075$, $b=1$)										
-15.717	-	-	-4.191	-3.362	-2.783	-2.346	-1.995	-1.698	-1.429	-1.163
($p=15$, $c=0.1$, $b=0.5$)										
-16.729	-	-	-6.908	-5.671	-4.721	-3.944	-3.277	-2.678	-2.117	-1.566
($p=15$, $c=0.1$, $b=1$)										
-15.883	-8.235	-5.619	-4.259	-3.403	-2.796	-2.329	-1.947	-1.614	-1.305	-0.987

Table 11: KS distances of α distributions between two markets for each incentive configuration

pair	KS distance
$p = 10, c = 0.1, b = 1$	
M-D	0.587
M-Q	0.781
D-Q	0.399
$p = 10, c = 0.075, b = 1$	
M-D	0.654
M-Q	0.825
D-Q	0.388
$p = 15, c = 0.1, b = 0.5$	
M-D	0.662
M-Q	0.828
D-Q	0.504
$p = 15, c = 0.1, b = 1$	
M-D	0.737
M-Q	1
D-Q	0.532

pair	KS distance
$p = 10, c = 0.1, b = 0.5$	
M-D	0.521
M-Q	0.873
D-Q	0.554
$p = 10, c = 0.075, b = 0.5$	
M-D	0.595
M-Q	0.742
D-Q	0.399
$p = 15, c = 0.075, b = 1$	
M-D	1
M-Q	1
D-Q	0.559
$p = 15, c = 0.075, b = 0.5$	
M-D	0.831
M-Q	1
D-Q	0.679

Table 12: KS distances of α distributions between two markets for each incentive configuration

	KS distances		
pair	Monoply	Duopoly	Quadropoly
1-2	0.227	0.327	0.260
1-3	0.512	0.329	0.382
1-4	0.169	0.183	0.399
1-5	0.432	0.313	0.440
1-6	0.382	0.199	0.244
1-7	0.152	0.715	0.803
1-8	0.449	0.413	0.803
2-3	0.582	0.305	0.343
2-4	0.327	0.199	0.343
2-5	0.540	0.482	0.393
2-6	0.440	0.307	0.285
2-7	0.183	0.648	0.748
2-8	0.507	0.282	0.748
3-4	0.465	0.504	0.343
3-5	0.144	0.177	0.255
3-6	0.365	0.216	0.341
3-7	0.582	0.504	0.557
3-8	0.271	0.504	0.557
4-5	0.379	0.346	0.335
4-6	0.288	0.307	0.463
4-7	0.252	0.532	0.607
4-8	0.404	0.335	0.607
5-6	0.252	0.374	0.335
5-7	0.526	0.681	0.499
5-8	0.155	0.681	0.498
6-7	0.376	0.612	0.739
6-8	0.149	0.307	0.739
7-8	0.471	0.482	0.595

Appendix C Robustness: alternate utility function, and between-subject subsample

6.1 C.1 Constant absolute risk aversion utility

Instead of the linear utility function, we now assume that utility takes the form $U(x) = 1 - \exp(-0.1x)$, where the coefficient of absolute risk aversion is set at 0.1. So the utility is $\alpha bq + [1 - \exp(-0.1(p - cq^2))]$. Table 13 reports the means of estimated α's in monopoly.

Table 13: Estimated means of α in monopoly under CARA

Incentive configurations	mean
($p = 10$, $c = 0.075$, $b = 0.5$)	0.066
($p = 10$, $c = 0.075$, $b = 1$)	0.033
($p = 10$, $c = 0.1$, $b = 0.5$)	0.084
($p = 10$, $c = 0.1$, $b = 1$)	0.041
($p = 15$, $c = 0.075$, $b = 0.5$)	0.051
($p = 15$, $c = 0.075$, $b = 1$)	0.026
($p = 15$, $c = 0.1$, $b = 0.5$)	0.071
($p = 15$, $c = 0.1$, $b = 1$)	0.034

The relative magnitudes between these means are quite close to those for the linear utility function in Table 3. For example, the mean α in incentive configuration ($p = 10$, $c = 0.075$, $b = 0.5$) is two times of that in configuration ($p = 10$, $c = 0.075$, $b = 1$). The same is true for the linear utility model; see the first two rows in Table 3. Using the same normalization (subtracting from each α the monopoly mean), we report the means and standard deviations of estimated α's in Duopoly and Quadropoly in Table 14.

Table 14: Normalized means and standard deviations of α distributions under CARA

Incentive configurations	Monopoly		Duopoly		Quadropoly	
	mean	st. dev.	mean	st. dev.	mean	st. dev.
($p = 10$, $c = 0.075$, $b = 0.5$)	0	0.059	-0.083	0.067	-0.098	0.054
($p = 10$, $c = 0.075$, $b = 1$)	0	0.030	-0.050	0.042	-0.062	0.043
($p = 10$, $c = 0.1$, $b = 0.5$)	0	0.082	-0.086	0.073	-0.143	0.112
($p = 10$, $c = 0.1$, $b = 1$)	0	0.040	-0.054	0.052	-0.068	0.054
($p = 15$, $c = 0.075$, $b = 0.5$)	0	0.045	-0.105	0.050	-0.126	0.051
($p = 15$, $c = 0.075$, $b = 1$)	0	0.023	-0.065	0.040	-0.078	0.058
($p = 15$, $c = 0.1$, $b = 0.5$)	0	0.069	-0.104	0.078	-0.127	0.065
($p = 15$, $c = 0.1$, $b = 1$)	0	0.033	-0.062	0.046	-0.078	0.053

Again, the means have all become lower when the market becomes more competitive. The differences between the normalized duopoly and quadropoly means also point in the same direction as those in the linear utility model although the magnitudes have now become smaller (see Table 4).

We conduct KS tests between altruism distributions as in Subsection 4.4. In Figure 14, we plot the empirical distribution functions of all 24 altruism distributions. We again reject the equality of altruism distributions for all comparisons except for a few cases under monopoly. Even after Bonferroni correction, the majority of comparisons (105 out of 108) remain significant at 1%. After Bonferroni correction, we fail to reject the hypotheses even at 10% for comparisons ($p = 10, c = 0.1, b = 1$) vs. ($p = 15, c = 0.1, b = 1$); ($p = 10, c = 0.075, b = 1$) vs. ($p = 15, c = 0.1, b = 1$); and ($p = 15, c = 0.1, b = 0.5$) vs. ($p = 10, c = 0.1, b = 0.5$) under monopoly.

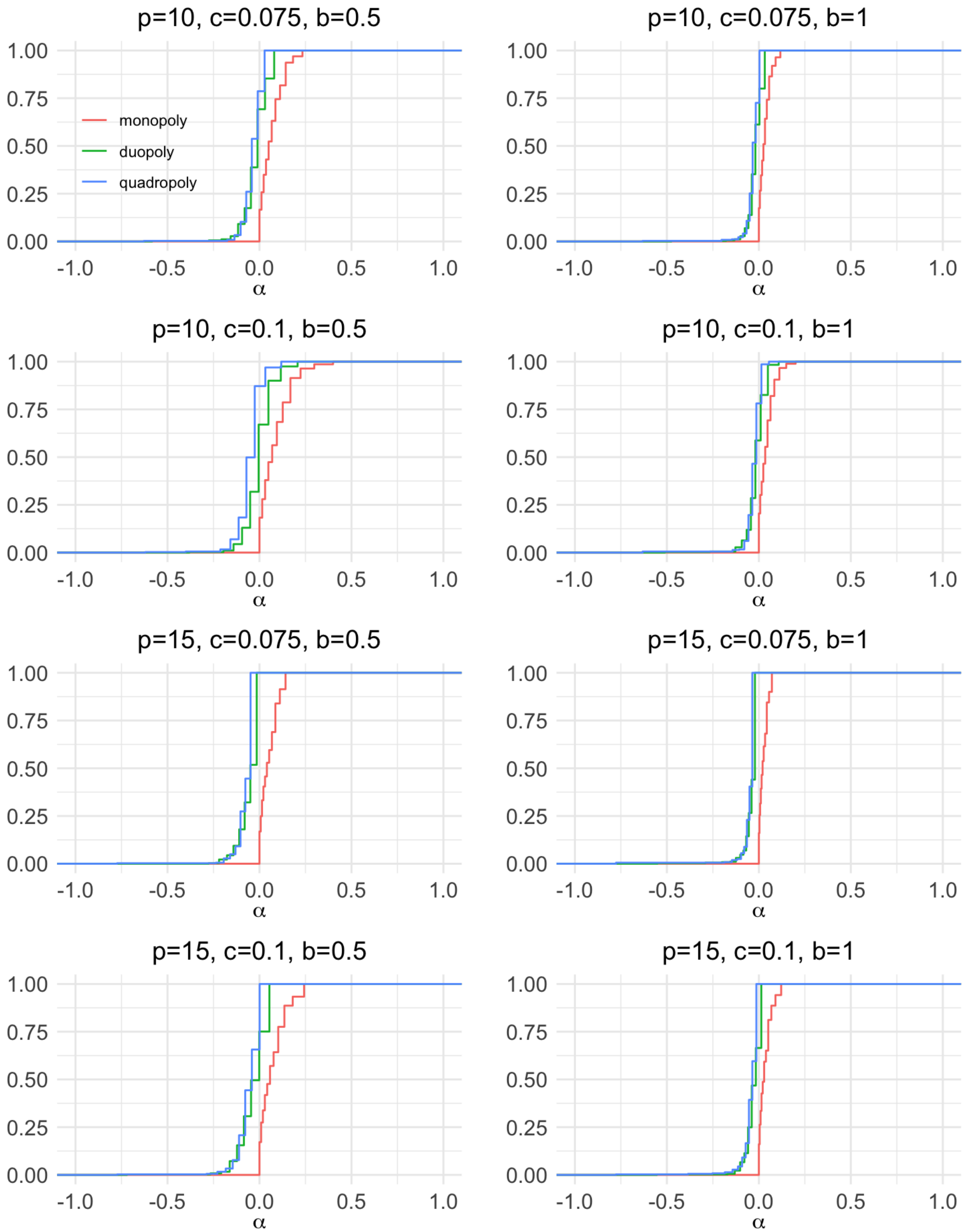


Figure 14: Distributions of estimated α in each market and in each incentive configuration under CARA.

C.2 Between-subject subsample

We use subjects' first experiences for a between-subject experiment. From Table 1, roughly a third of the 361 subjects played each of the three markets in their first round, so we only can use about 1/3 of the entire data. In the experiments, 124 subjects played the monopoly game first, 119 played the duopoly first, and 118 played the quadropoly first. The 8 decisions of these first games form the subsample.

Table 15 presents the first-round summary statistics of the 8 incentive-configuration games in the 3 markets. There are some small differences in the means and standard deviations between the smaller, between-subject subsample and the full sample. Nevertheless, the means and standard deviations follow the same pattern in Table 2. Figures 15 to 17 present the quality choice distributions by incentive configurations for the three markets.

Table 15: Between-subject subsample summary statistics

Incentive configurations	Monopoly ($n = 124$)		Duopoly ($n = 119$)		Quadropoly ($n = 118$)	
	mean	st. dev.	mean	st. dev.	mean	st. dev.
($p = 10$, $c = 0.075$, $b = 0.5$)	4.403	2.659	7.437	1.701	7.958	1.577
($p = 10$, $c = 0.075$, $b = 1$)	4.460	2.688	7.765	1.598	8.017	1.764
($p = 10$, $c = 0.1$, $b = 0.5$)	4.065	2.569	6.597	1.463	6.932	1.688
($p = 10$, $c = 0.1$, $b = 1$)	3.871	2.521	6.622	1.408	6.958	1.538
($p = 15$, $c = 0.075$, $b = 0.5$)	5.113	3.007	8.420	1.670	8.780	1.675
($p = 15$, $c = 0.075$, $b = 1$)	5.266	3.021	8.672	1.698	8.898	1.892
($p = 15$, $c = 0.1$, $b = 0.5$)	4.823	2.891	7.664	1.801	8.102	1.692
($p = 15$, $c = 0.1$, $b = 1$)	4.734	2.930	8.000	1.616	8.254	1.949

Table 16 presents the means of estimated α's in Monopoly, and they are similar to those in the full sample in Table 3.

Table 16: Estimated means of α in monopoly for the between-subject subsample

Incentive configurations	mean
($p = 10$, $c = 0.075$, $b = 0.5$)	1.321
($p = 10$, $c = 0.075$, $b = 1$)	0.669
($p = 10$, $c = 0.1$, $b = 0.5$)	1.626
($p = 10$, $c = 0.1$, $b = 1$)	0.774
($p = 15$, $c = 0.075$, $b = 0.5$)	1.534
($p = 15$, $c = 0.075$, $b = 1$)	0.790
($p = 15$, $c = 0.1$, $b = 0.5$)	1.929
($p = 15$, $c = 0.1$, $b = 1$)	0.947

In Table 17, we present the means and standard deviations of estimated α's in duopoly and quadropoly (under the same normalization as before). There are some differences from Table 4. In particular, the means tend to be higher in magnitude than those in the full sample. The standard deviations are also bigger, but that can be accounted for by the smaller sample size.

Table 17: Normalized means and standard deviations of α distributions for the between-subject subsample

Incentive configurations	Monopoly		Duopoly		Quadropoly	
	mean	st. dev.	mean	st. dev.	mean	st. dev.
$(p = 10,\ c = 0.075,\ b = 0.5)$	0	0.798	-1.532	1.170	-1.789	1.076
$(p = 10,\ c = 0.075,\ b = 1)$	0	0.403	-0.893	0.531	-1.141	1.005
$(p = 10,\ c = 0.1,\ b = 0.5)$	0	1.027	-1.639	1.053	-2.762	2.782
$(p = 10,\ c = 0.1,\ b = 1)$	0	0.504	-1.011	0.588	-1.315	1.322
$(p = 15,\ c = 0.075,\ b = 0.5)$	0	0.902	-2.188	1.045	-2.665	1.511
$(p = 15,\ c = 0.075,\ b = 1)$	0	0.453	-1.345	0.733	-1.743	1.903
$(p = 15,\ c = 0.1,\ b = 0.5)$	0	1.156	-2.377	1.708	-2.832	1.641
$(p = 15,\ c = 0.1,\ b = 1)$	0	0.586	-1.323	0.706	-1.743	1.585

We next present the histograms of the actual qualities in the subsample in Figures 15, 16, and 17, with the frequencies written on top of each quality value. Qualities in monopoly in the full and between-subject subsample show more variations. However, the duopoly and quadropoly quality distributions are remarkably similar.

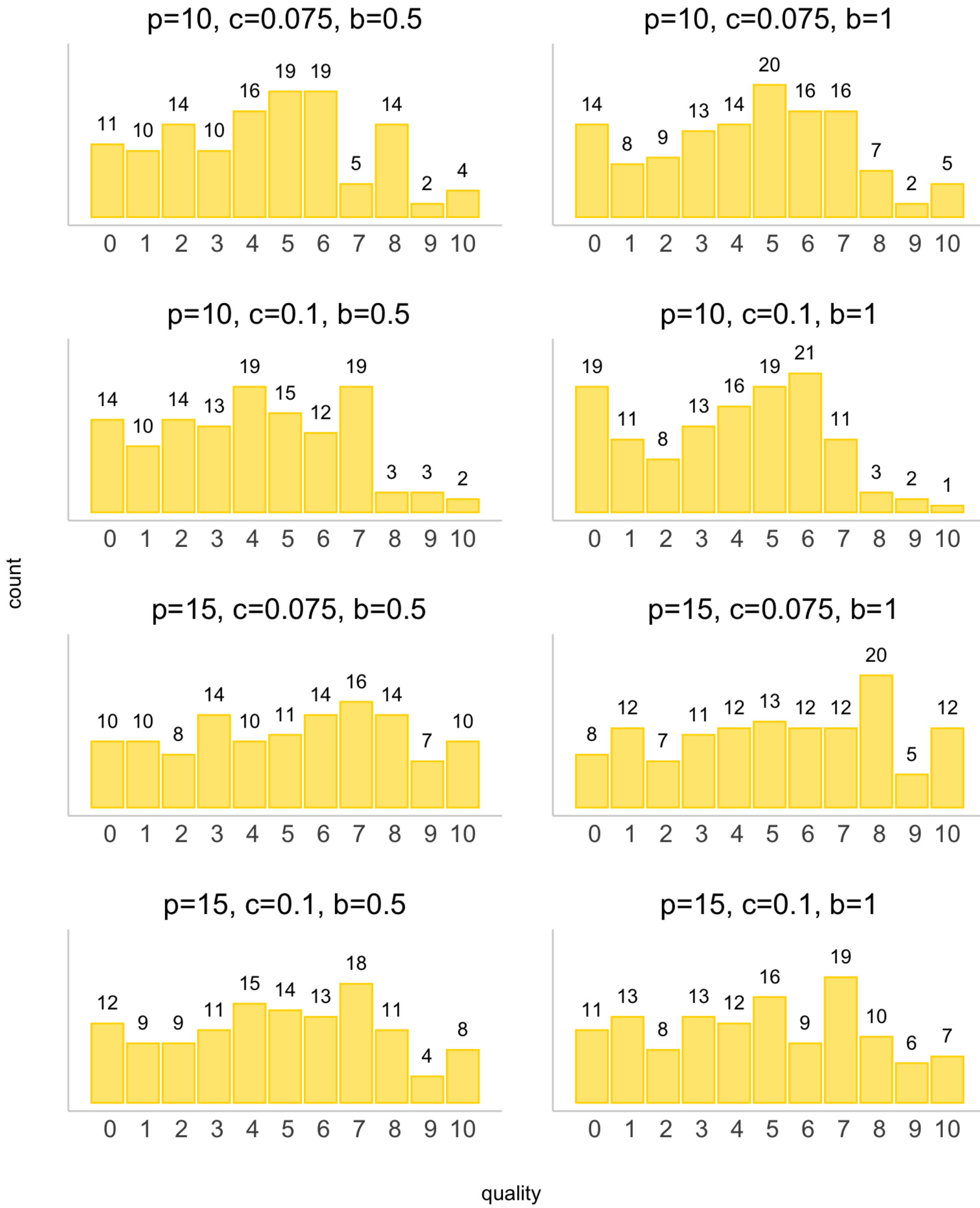


Figure 15: Between-subject quality histograms in monopoly

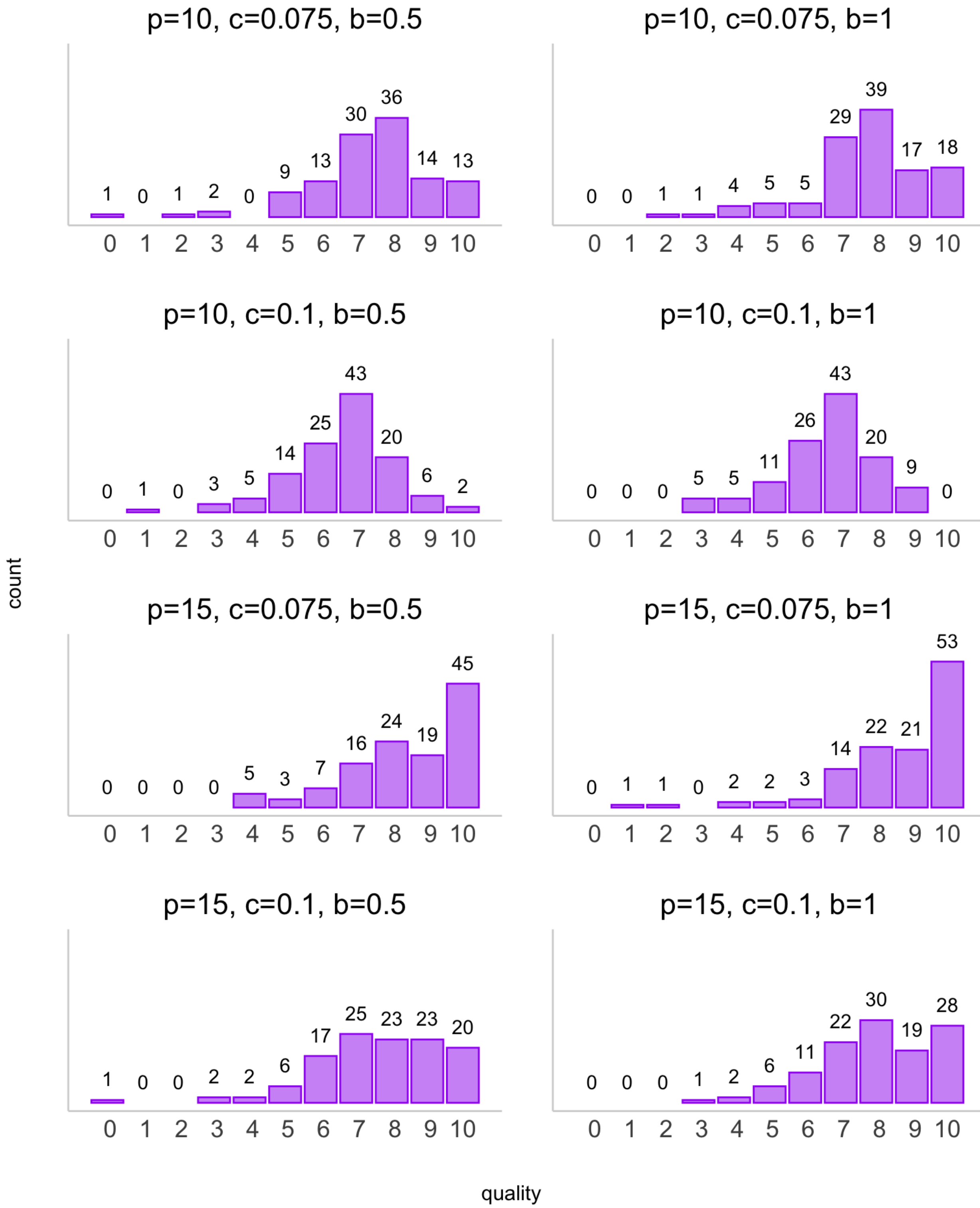


Figure 16: Between-subject quality histograms in duopoly

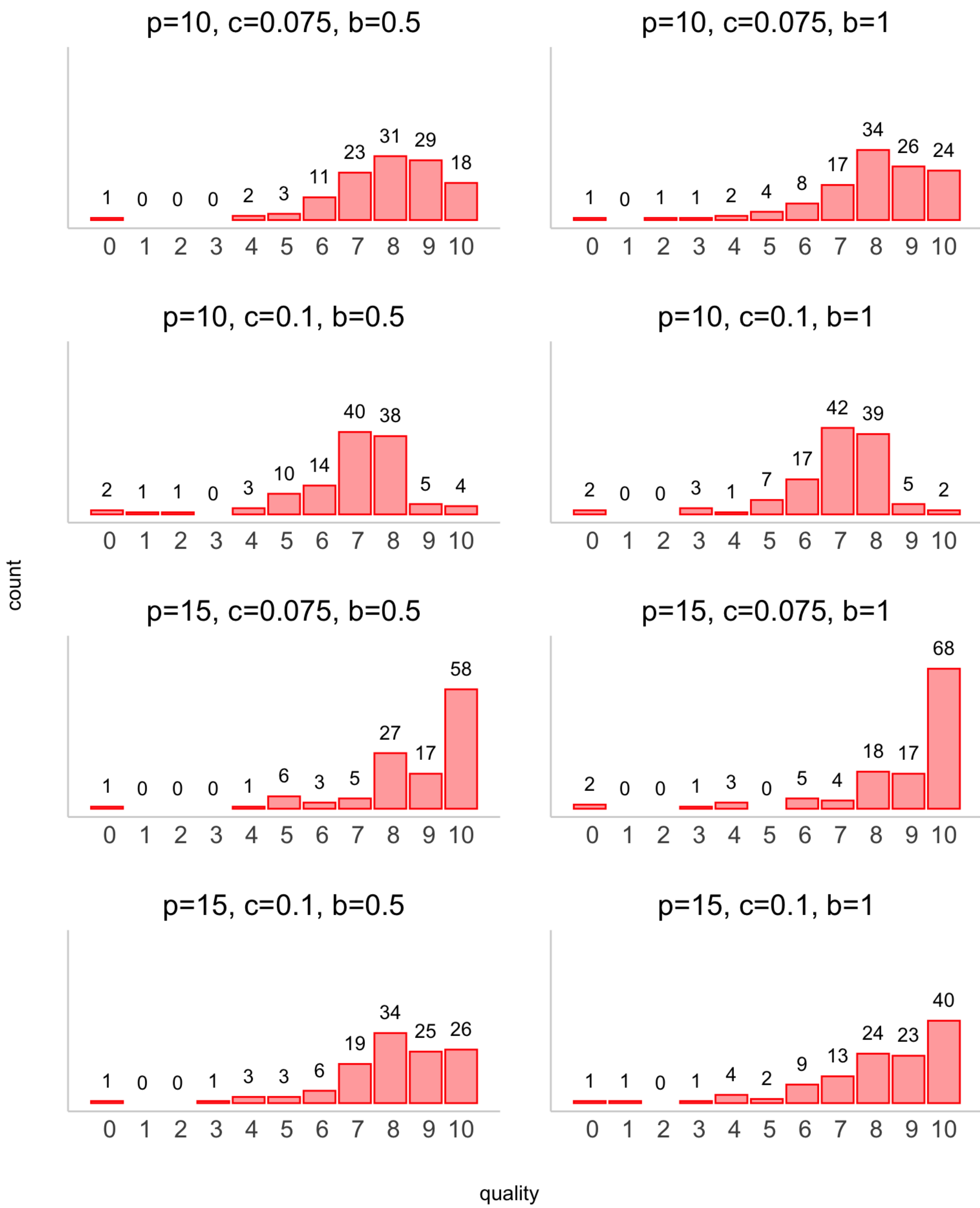


Figure 17: Between-subject quality histograms in quadropoly

In Figure 18, we plot the empirical distribution functions of all 24 altruism distributions. We again reject the equality of altruism distributions for all comparisons except for a few cases under monopoly. Even after Bonferroni correction, the majority of comparisons (88 out of 108) remain significant at 1%. After Bonferroni correction, the following comparisons remain significant at 10%: $(p = 10, c = 0.1, b = 1)$ vs. $(p = 10, c = 0.075, b = 1)$ under monopoly and $(p = 10, c = 0.075, b = 1)$ vs. $(p = 15, c = 0.1, b = 1)$ under duopoly. Moreover, the following comparisons remain significant at 5% after Bonferroni correction: $(p = 15, c = 0.1, b = 1)$ vs. $(p = 15, c = 0.075, b = 1)$ and $(p = 10, c = 0.1, b = 0.5)$ vs. $(p = 10, c = 0.075, b = 0.5)$ under monopoly; $(p = 10, c = 0.1, b = 1)$ vs. $(p = 15, c = 0.1, b = 0.5)$ and $(p = 10, c = 0.1, b = 1)$ vs. $(p = 10, c = 0.075, b = 0.5)$ under duopoly; $(p = 10, c = 0.1, b = 1)$ vs. $(p = 15, c = 0.1, b = 1)$ under quadropoly.

After Bonferroni correction, we fail to reject the hypotheses even at 10% for the following comparisons under monopoly: $(p = 10, c = 0.1, b = 1)$ vs. $(p = 15, c = 0.1, b = 1)$; $(p = 10, c = 0.1, b = 1)$ vs. $(p = 15, c = 0.075, b = 1)$; $(p = 10, c = 0.075, b = 1)$ vs. $(p = 15, c = 0.075, b = 1)$; $(p = 15, c = 0.1, b = 0.5)$ vs. $(p = 10, c = 0.1, b = 0.5)$; $(p = 10, c = 0.1, b = 0.5)$ vs. $(p = 15, c = 0.075, b = 0.5)$; $(p = 10, c = 0.075, b = 0.5)$ vs. $(p = 15, c = 0.075, b = 0.5)$. Under duopoly, we fail the reject the equivalence between the following distributions: $(p = 10, c = 0.1, b = 1)$ vs. $(p = 15, c = 0.1, b = 1)$; $(p = 10, c = 0.075, b = 1)$ vs. $(p = 10, c = 0.075, b = 0.5)$; $(p = 15, c = 0.1, b = 0.5)$ vs. $(p = 10, c = 0.1, b = 0.5)$; $(p = 15, c = 0.1, b = 0.5)$ vs. $(p = 10, c = 0.075, b = 1)$; $(p = 15, c = 0.075, b = 0.5)$ vs. $(p = 15, c = 0.075, b = 0.5)$. Under quadropoly, we fail to reject the equivalance for $(p = 10, c = 0.075, b = 1)$ vs. $(p = 10, c = 0.075, b = 0.5)$. We also fail to reject the equivalence between $(p = 10, c = 0.1, b = 1)$ under duopoly vs. $(p = 10, c = 0.1, b = 1)$ under quadropoly.

Overall, we think that our results are robust with respect to between-subject and within-subject designs.

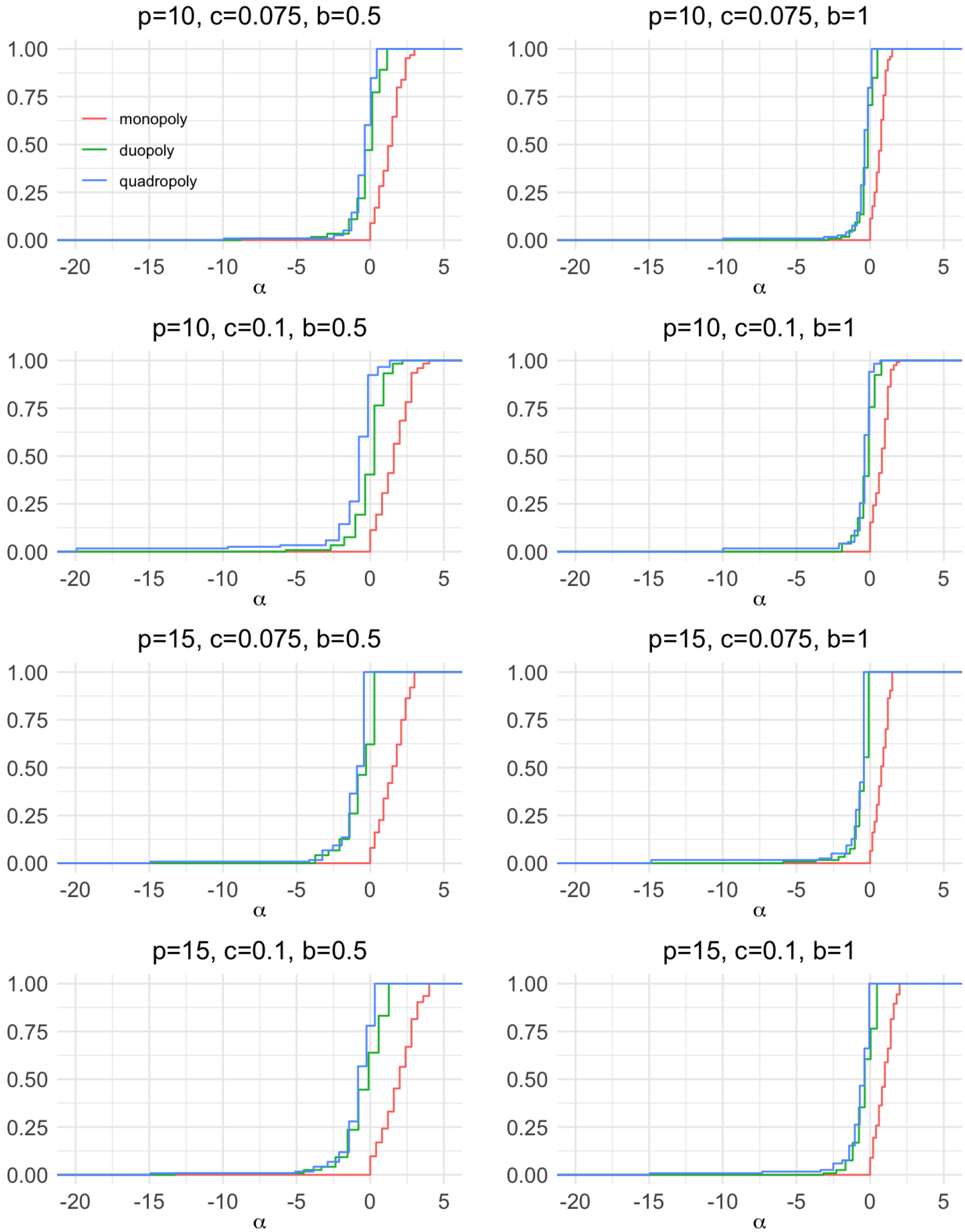


Figure 18: Distributions of estimated α in each market and in each incentive configuration for the between-subject subsample.

C.2.1 Reduced-form analysis for between-subject subsample

Table 18 reports descriptive statistics on subjects' first-experience average qualities for low and high prices, costs, and patient benefits. The entries are written with the same convention as in Table 5. The average qualities in Table 18 exhibit the same pattern as those in Table 5. The average quality is higher in each market at the higher price, but the relative difference declines as the market becomes more competitive. Average qualities are lower at higher cost, but the relative difference hardly varies with competition. Patient benefit does not seem to affect average qualities much. We conclude that the reduced-form analysis is robust with respect to the between-subject and within-subject designs.

Table 18: Descriptives on price-cost-benefit variations in subjects' first market interactions

	Low parameter		High parameter		Relative	N
Parameter	mean	st. dev.	mean	st. dev.	difference	
Price ($p = 10$; $p = 15$)						
Monopoly	4.200	2.614	4.984	2.962	0.187	496
Duopoly	7.105	1.736	8.189	1.623	0.153	476
Quadropoly	7.466	1.720	8.509	1.832	0.140	472
Cost ($c = 0.075$; $c = 0.1$)						
Monopoly	4.811	2.866	4.373	2.757	-0.091	496
Duopoly	8.074	1.734	7.221	1.693	-0.106	476
Quadropoly	8.413	1.778	7.561	1.826	-0.101	472
Patient benefit ($b = 0.5$; $b = 1$)						
Monopoly	4.601	2.807	4.583	2.834	-0.004	496
Duopoly	7.529	1.781	7.765	1.743	0.031	476
Quadropoly	7.943	1.781	8.032	1.919	0.011	472

Regression results for the between-subject analysis are reported in Table 19. The notation here is the same as in Table 6, except of course that there are no market-order dummies. Because of the smaller sample, the R^2's are uniformly smaller than regressions in Table 6. Most estimates happen to be a little smaller in their magnitudes than in Table 6, but their significance remains the same.

Table 19: Between-subject quality regressions

Model:	(1)	(2)
Dependent variable:	Quality	Quality
Duopoly	3.194***	3.125***
	(0.373)	(0.371)
Quadropoly	3.809***	3.834***
	(0.391)	(0.387)
High price (= 1 if $p = 15$)	0.967***	0.784***
	(0.0459)	(0.0761)
High cost (= 1 if $c = 0.1$)	-0.710***	-0.437***
	(0.0437)	(0.0811)
High benefit (= 1 if $b = 1$)	0.100**	-0.0181
	(0.0423)	(0.0660)
Duopoly × High price		0.300***
		(0.107)
Quadropoly × High price		0.258**
		(0.114)
Duopoly × High cost		-0.415***
		(0.111)
Quadropoly × High cost		-0.414***
		(0.102)
Duopoly × High benefit		0.253**
		(0.101)
Quadropoly × High benefit		0.107
		(0.101)
Session dummies	Yes	Yes
Constant	4.051***	4.066***
	(0.334)	(0.331)
Observations	2,888	2,888
Subjects	361	361
R^2	0.386	0.388

Online Appendix

Changing Preferences: An Experiment and Estimation of Market-Incentive Effects on Altruism

Undral Byambadalai, Ching-to Albert Ma, Daniel Wiesen

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1 Extended concern

Here, we allow for a set of more general preferences; a subject is assumed to value the quality that a patient receives from another subject. We present only a duopoly model in some details; quadropoly is similar. A subject's preferences has two parameters, α and β. If a subject provides quality q to his own patient, his utility is the same as before: $\alpha bq + U(p - cq^2)$. If a patient receives quality q' from a rival subject, the subject's utility becomes $\beta bq'$; this is what we mean by a subject's extended concern, and the parameter β is the degree of concern when another subject provides quality q'.

As before we let a subject's market share be given by a logistic demand:

$$S(q_1; q') \equiv \frac{\exp(bq_1)}{\exp(bq_1) + \exp(bq')},$$

where q_1 is the subject's quality and q' is the rival's quality. Given these qualities, the subject's payoff now becomes

$$S(q_1; q')[\alpha bq_1 + U(p - cq_1^2)] + [1 - S(q_1; q')]\beta bq'.$$

The subject gets $S(q_1; q')$ of all 100 patients, who receive his quality q_1, and the other $1 - S(q_1; q')$ of 100 patients receive quality q' from the rival.

We continue to assume that α is a random variable, but begin by assuming that β is a fixed constant. We discuss later the alternative assumption of β being random. If we set β to 0, then we eliminate extended concern, so the main model is a special case.

A subject's strategy is $q : [\underline{\alpha}, \overline{\alpha}] \to [0, 10]$. If the subject chooses quality q_1, his expected utility is

$$\int_{\alpha'} S(q_1; q(\alpha'))[\alpha b q_1 + U(p - cq_1^2)]\mathrm{d}F(\alpha') + \int_{\alpha'} [1 - S(q_1; q(\alpha'))]\beta b q(\alpha')\mathrm{d}F(\alpha'),$$

where we have omitted 100 for the total number of consumers. The two integrals, respectively, are the subject's utility when he provides quality q_1 to his share of the market $S(q_1; q(\alpha'))$, and when the other subject provides $q(\alpha')$ to the rest of the market $1 - S(q_1; q(\alpha'))$. We simplify the expected utility to

$$\int_{\alpha'} S(q_1; q(\alpha'))[\alpha b q_1 + U(p - cq_1^2)]\mathrm{d}F(\alpha') - \int_{\alpha'} S(q_1; q(\alpha'))\beta b q(\alpha')]\mathrm{d}F(\alpha') + \int_{\alpha'} \beta b q(\alpha')\mathrm{d}F(\alpha').$$

For a given strategy q, extended concern is represented by the second and third integrals. However, the last integral does not vary with q_1; the second integral does vary negatively with quality q_1, but only through the market share. The first-order derivative of the subject's expected utility with respect to q_1 is

$$\int_{\alpha'} \frac{\partial S(q_1; q(\alpha')}{\partial q_1})[\alpha b q_1 + U(p - cq_1^2) - \beta b q(\alpha')]\mathrm{d}F(\alpha') + \int_{\alpha'} S(q_1; q(\alpha'))[\alpha b - 2cq_1 U'(p - cq_1^2)]\mathrm{d}F(\alpha').$$

A subject's extended concern serves to reduce quality provision due to altruism. A subject enjoys utility from a rival subject's quality provision, so free rides on the rival's quality provision. An extended concern has muted incentive to supply quality.

An alternative assumption is that β is random. Then α and β have a joint distribution. Such an assumption would make our model unidentified. We are unaware of any method that can help us estimate such a joint distribution from data in our experiment. A special case, however, is that α and β are perfectly correlated: a subject values quality from a rival for any subject in a similiar way as the subject's own quality, $\beta = k\alpha$, for some constant $k \geq 0$. Then we rewrite the above first-order derivative as

$$\int_{\alpha'} \frac{\partial S(q_1; q(\alpha')}{\partial q_1})[\alpha b(q_1 - kq(\alpha')) + U(p - cq_1^2)]\mathrm{d}F(\alpha') + \int_{\alpha'} S(q_1; q(\alpha'))[\alpha b - 2cq_1 U'(p - cq_1^2)]\mathrm{d}F(\alpha').$$

Setting this to zero yields the characterization of the optimal q_1. We can reuse the expressions for the partial derivative of the market share to simplify the first-order condition further. Then we can use the first-order condition to solve for α in terms of the equilibrium q^*. The expression is

$$\alpha = \frac{\left\{ \begin{array}{c} 2cq^*(\alpha)U'(p - cq^*(\alpha)^2)\int_{\underline{\alpha}}^{\overline{\alpha}} S(q^*(\alpha); q^*(x))\mathrm{d}F(x) \\ \\ -U(p - cq^*(\alpha)^2) \times b\int_{\underline{\alpha}}^{\overline{\alpha}} S(q^*(\alpha); q^*(x))[1 - S(q^*(\alpha); q^*(x))]\mathrm{d}F(x) \end{array} \right\}}{\left\{ \begin{array}{c} b\int_{\underline{\alpha}}^{\overline{\alpha}} S(q^*(\alpha); q^*(x))\mathrm{d}F(x) \\ \\ +b\int_{\underline{\alpha}}^{\overline{\alpha}} [q^*(\alpha) - kq^*(x)]bS(q^*(\alpha); q^*(x))[1 - S(q^*(\alpha); q^*(x))]\mathrm{d}F(x) \end{array} \right\}},$$

which differs from the corresponding nonparametric estimation formula by the term $[q^*(\alpha) - kq^*(x)]$ instead of $q^*(\alpha)$ in the denominator.

However, the cross partial derivative of the expected utility is the partial derivative of

$$\int_{\alpha'} \frac{\partial S(q_1; q(\alpha')}{\partial q_1})[\alpha b(q_1 - kq(\alpha')) + U(p - cq_1^2)]\mathrm{d}F(\alpha')$$

with respect to α. This is

$$\int_{\alpha'} \frac{\partial S(q_1; q(\alpha')}{\partial q_1})[b(q_1 - kq(\alpha'))]\mathrm{d}F(\alpha'),$$

which may not be positive. The monotonicity of equilibrium quality with altruism α may not hold, and our estimation procedure fails. Monotonicity is guaranteed only if k is sufficiently small. Indeed, we have verified that, for small values of k (say 0.1, or 0.15), the estimated α distributions are similar to those in the main model. Our take is that a model of extended concern seems untenable because such a component implies free riding in an equilibrium.

For completeness, we write down the relevant formulas in quadropoly. Suppose that q^{**} is an equilibrium quality strategy, we have the following for subject i's equilibrium quality choice of quality when the subject's altruism is α_i and when extended concern has $\beta = k\alpha$

$$q^{**}(\alpha_i) = \underset{q}{\operatorname{argmax}}\ [\alpha_i bq + U(p - cq^2)] \int\int\int \{S(q; q^{**}_{-i}(\alpha_{-i}))\} \prod_{j=1,\ j\neq i}^{4} \mathrm{d}K(\alpha_j) +$$

$$k\alpha_i \int\int\int \{q^{**}(\alpha_j)[1 - S(q; q^{**}_{-i}(\alpha_{-i})]\} \prod_{j=1,\ j\neq i}^{4} \mathrm{d}K(\alpha_j).$$

The first-order derivative with respect to q is

$$\int\int\int \left\{ \frac{S(q; q_{-i}^{**}(\alpha_{-i}))}{\partial q} [\alpha_i b(q - kq^{**}(\alpha_j)) + U(p - cq^2)] \right\} \prod_{j=1,\ j \neq i}^{4} \mathrm{d}K(\alpha_j) +$$

$$\int\int\int S(q; q_{-i}^{**})[\alpha b - 2cqU'(p - cq^2)] \prod_{j=1,\ j \neq i}^{4} \mathrm{d}K(\alpha_j).$$

Solving for α_i after putting the first-order derivative to zero yields

$$\alpha_i = \frac{\left\{ \begin{array}{c} 2cq^{**}(\alpha_i)U'(p - cq^{**}(\alpha_i)^2) \int\int\int S(q^{**}(\alpha_i); q_{-i}^{**}(\alpha_{-i})) \prod_{j=1,\ j \neq i}^{4} \mathrm{d}K(\alpha_j) \\ -U(p - cq^{**}(\alpha_i)^2) \times b \int\int\int S(q^{**}(\alpha_i); q_{-i}^{**}(\alpha_{-i}))[1 - S(q^{**}(\alpha_i); q_{-i}^{**}(\alpha_{-i}))] \prod_{j=1,\ j \neq i}^{4} \mathrm{d}K(\alpha_j) \end{array} \right\}}{\left\{ \begin{array}{c} b \int\int\int S(q^{**}(\alpha_i); q_{-i}^{**}(\alpha_{-i})) \prod_{j=1,\ j \neq i}^{4} \mathrm{d}K(\alpha_j) \\ +b \int\int\int [q^{**}(\alpha_i) - kq_j^{**}(\alpha_j)] bS(q^{**}(\alpha_i); q_{-i}^{**}(\alpha_{-i}))[1 - S(q^{**}(\alpha_i); q_{-i}^{**}(\alpha_{-i}))] \prod_{j=1,\ j \neq i}^{4} \mathrm{d}K(\alpha_j) \end{array} \right\}}.$$

2 Asymmetric Bayes-Nash equilibria

We describe the construction of asymmetric Bayes-Nash equilibria for a duopoly. Suppose that there are two players, subject A and subject B. Let subject A use a strategy $q_A : [\underline{\alpha}, \overline{\alpha}] \to [0, 10]$, and let subject B use a straregy $q_B : [\underline{\alpha}, \overline{\alpha}] \to [0, 10]$. Given subject B's strategy q_B, subject A's expected utility is

$$\mathrm{EU}(q_1; q_B) = [\alpha b q_1 + U(p - cq_1^2)] \times \int_{\underline{\alpha}}^{\overline{\alpha}} 100 S(q_1; q_B(x)) \mathrm{d}F(x),$$

when his altruism parameter is α. Given subject A's strategy q_A, subject B's expected utility is

$$\mathrm{EU}(q_2; q_A) = [\alpha b q_2 + U(p - cq_1^2)] \times \int_{\underline{\alpha}}^{\overline{\alpha}} 100 S(q_1; q_B(x)) \mathrm{d}F(x).$$

The strategy profile (q_A, q_B) is a Bayes-Nash equilibrium if at each α:

$$q_A(\alpha) \in \underset{q_1}{\mathrm{argmax}} [\alpha b q_1 + U(p - cq_1^2)] \times \int_{\underline{\alpha}}^{\overline{\alpha}} 100 S(q_1; q_B(x)) \mathrm{d}F(x)$$

$$q_B(\alpha) \in \underset{q_2}{\mathrm{argmax}} [\alpha b q_2 + U(p - cq_1^2)] \times \int_{\underline{\alpha}}^{\overline{\alpha}} 100 S(q_A(x); q_2) \mathrm{d}F(x).$$

An equilibrium is said to be asymmetric if $q_A \neq q_B$. Essentially, finding an asymmetric Bayes-Nash equilibrium is finding solutions of a pair of simultaneous integral equations (the first-order conditions for optimal choices of qualities being integrated over the rival's types).

With many subjects, asymmetric equilibria may be very complicated. For example, in a quadropoly, two subjects may choose one strategy, whereas each of the other two may choose a distinct strategy. In the extant empirical industrial organization or microeconomics literature, we are unable to find studies that aim to estimate asymmetric Bayes-Nash equilibria. They are analytically difficult to characterize, and there is no known structural estimation method.

In our context, we have randomly matched subjects, who always remain anonymous. Each game is a symmetric game, so it is reasonable to suppose that a symmetric equilibrium may become a focal point.

3 Allowing corner solutions at maximum quality

A subject is supposed to choose a quality $q \in \{0, 1, ..., 9, 10\}$. A negative quality is infeasible because there is no extra payment (due to negative cost to subjects). However, one may suspect that on some occasions, a subject would have preferred to choose a higher quality than the maximum 10, which formally means that the maximum quality might have been a corner solution. We postulate that when a subject chooses $q = 10$, the subject actually would aim to choose $q \in \{10, 11, 12\}$. We further postulate that the frequencies of $q = 10$ choices should be evenly spread over $q \in \{10, 11, 12\}$. In this section, we re-analyze the data under these hypotheses.

Table 1 presents the means of estimated α distributions in monopoly. Table 2 presents the means and standard deviations of 24 altruism distributions normalized at the mean values under monopoly. Even if we treat the maximum qualities as high as 12, the reduction in altruism from monopoly to duopoly and from duopoly to quadropoly seem obvious.

In Figure 1, we plot all 24 estimated altruism distributions. We conduct KS tests between altruism distributions as in Subsection 4.4 of the main paper. The results remain the same as in the main analysis. We again reject the equality of altruism distributions in all comparisons. Even after Bonferroni correction,

Table 1: Estimated means of α distribution in monopoly with maximum quality extrapolated to 12

Incentive configurations	Estimated mean
$p = 10, c = 0.075, b = 0.5$	1.262
$p = 10, c = 0.075, b = 1$	0.628
$p = 10, c = 0.1, b = 0.5$	1.521
$p = 10, c = 0.1, b = 1$	0.748
$p = 15, c = 0.075, b = 0.5$	1.473
$p = 15, c = 0.075, b = 1$	0.74
$p = 15, c = 0.1, b = 0.5$	1.832
$p = 15, c = 0.1, b = 1$	0.9

Table 2: Normalized means and standard deviations of α distributions with maximum quality extrapolated to 12

Incentive configurations	Monopoly		Duopoly		Quadropoly	
	mean	st. dev.	mean	st. dev.	mean	st. dev.
$p = 10, c = 0.075, b = 0.5$	0	0.92	-1.263	1.055	-1.509	0.871
$p = 10, c = 0.075, b = 1$	0	0.461	-0.739	0.704	-0.918	0.718
$p = 10, c = 0.1, b = 0.5$	0	1.134	-1.367	0.949	-2.205	1.761
$p = 10, c = 0.1, b = 1$	0	0.566	-0.876	0.744	-1.063	0.835
$p = 15, c = 0.075, b = 0.5$	0	1.073	-1.769	1.147	-2.208	1.132
$p = 15, c = 0.075, b = 1$	0	0.538	-1.065	0.871	-1.349	1.19
$p = 15, c = 0.1, b = 0.5$	0	1.358	-1.855	1.522	-2.292	1.32
$p = 15, c = 0.1, b = 1$	0	0.66	-1.054	0.971	-1.368	1.097

the majority of comparisons (104 out of 108) remain significant at 1%. The following comparisons under monopoly become significant at 5% after correction: ($p = 10, c = 0.1, b = 1$) vs ($p = 15, c = 0.075, b = 1$); ($p = 10, c = 0.1, b = 0.5$) vs ($p = 15, c = 0.075, b = 0.5$). For the comparison ($p = 10, c = 0.075, b = 0.5$) vs ($p = 15, c = 0.075, b = 0.5$) under monopoly, we can reject the hypothesis at 10%. However, we fail to reject the hypothesis for the comparison ($p = 15, c = 0.1, b = 0.5$) vs ($p = 10, c = 0.1, b = 0.5$) under monopoly after the Bonferroni correction (adjusted p-value is 0.12).

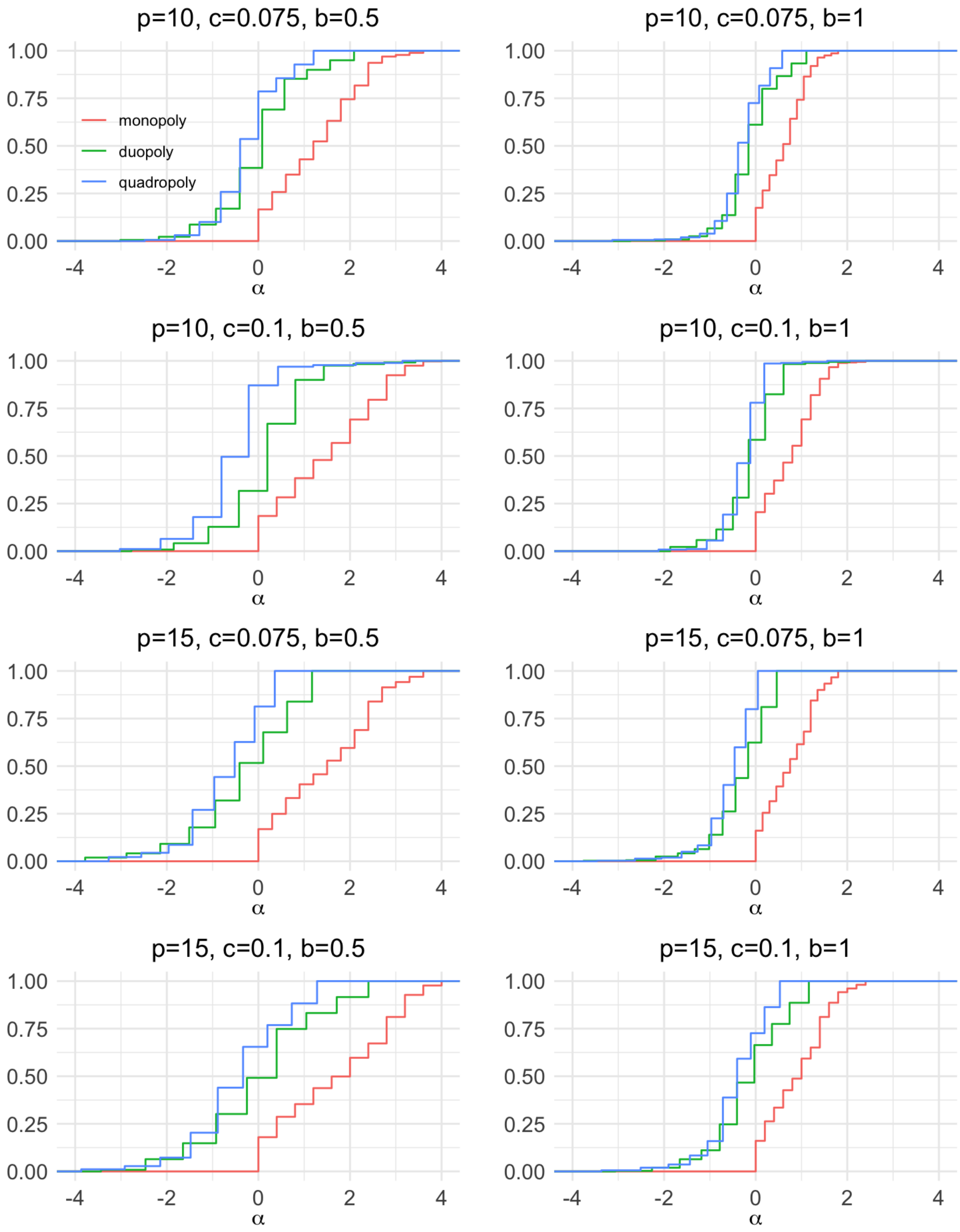

Figure 1: Distributions of estimated α in each market and in each incentive configuration (with corner cases extrapolated up to 12)

4 Constant Absolute Risk Aversion (CARA) Utility

In this section, instead of the linear utility function, we let utility take the form

$$U(x) = 1 - \exp(-rx).$$

In Appendix C.1 in the paper, we show the results where the coefficient of absolute risk aversion r is set at 0.10. Here, we report the results for $r = 0.05$ and $r = 0.15$.

4.1 Coefficient of absolute risk aversion $r = 0.05$

Table 3 presents the means of estimated α distributions in monopoly at $r = 0.05$. Table 4 presents the means and standard deviations of 24 altruism distributions normalized at the monopoly means. Under CARA specification, the differences between monopoly vs duopoly and duopoly vs quadropoly shrink. The magnitude of the difference is even smaller at $r = 0.05$ compared to $r = 0.10$ in Appendix C.1. However, we still reject the equality between distributions in all cases at 1% even after Bonferroni correction except for a few comparisons under monopoly. Those are ($p = 10, c = 0.1, b = 1$) vs ($p = 15, c = 0.1, b = 1$); ($p = 10, c = 0.075, b = 1$) vs ($p = 15, c = 0.075, b = 1$); ($p = 15, c = 0.1, b = 0.5$) vs ($p = 10, c = 0.1, b = 0.5$); and ($p = 10, c = 0.075, b = 0.5$) vs ($p = 15, c = 0.075, b = 0.5$). While the unadjusted p-values for these comparisons are 0.012, 0.037, 0.055, and 0.067 respectively, we fail to reject the hypothesis even at 10% for all 4 cases after Bonferroni correction. In Figure 2, we plot the 24 empirical altruism distributions at $r = 0.05$.

Table 3: Estimated means of α in monopoly under CARA at $r = 0.05$

Incentive configurations	Estimated mean
$p = 10, c = 0.075, b = 0.5$	0.045
$p = 10, c = 0.075, b = 1$	0.022
$p = 10, c = 0.1, b = 0.5$	0.056
$p = 10, c = 0.1, b = 1$	0.028
$p = 15, c = 0.075, b = 0.5$	0.043
$p = 15, c = 0.075, b = 1$	0.021
$p = 15, c = 0.1, b = 0.5$	0.056
$p = 15, c = 0.1, b = 1$	0.027

Table 4: Normalized means and standard deviations of α distributions under CARA at $r = 0.05$

Incentive configurations	Monopoly		Duopoly		Quadropoly	
	mean	st. dev.	mean	st. dev.	mean	st. dev.
$p = 10, c = 0.075, b = 0.5$	0	0.036	-0.052	0.04	-0.062	0.032
$p = 10, c = 0.075, b = 1$	0	0.018	-0.032	0.025	-0.039	0.026
$p = 10, c = 0.1, b = 0.5$	0	0.047	-0.054	0.04	-0.088	0.069
$p = 10, c = 0.1, b = 1$	0	0.023	-0.034	0.03	-0.042	0.033
$p = 15, c = 0.075, b = 0.5$	0	0.034	-0.07	0.034	-0.085	0.035
$p = 15, c = 0.075, b = 1$	0	0.017	-0.044	0.027	-0.052	0.04
$p = 15, c = 0.1, b = 0.5$	0	0.047	-0.07	0.05	-0.086	0.043
$p = 15, c = 0.1, b = 1$	0	0.023	-0.042	0.03	-0.052	0.036

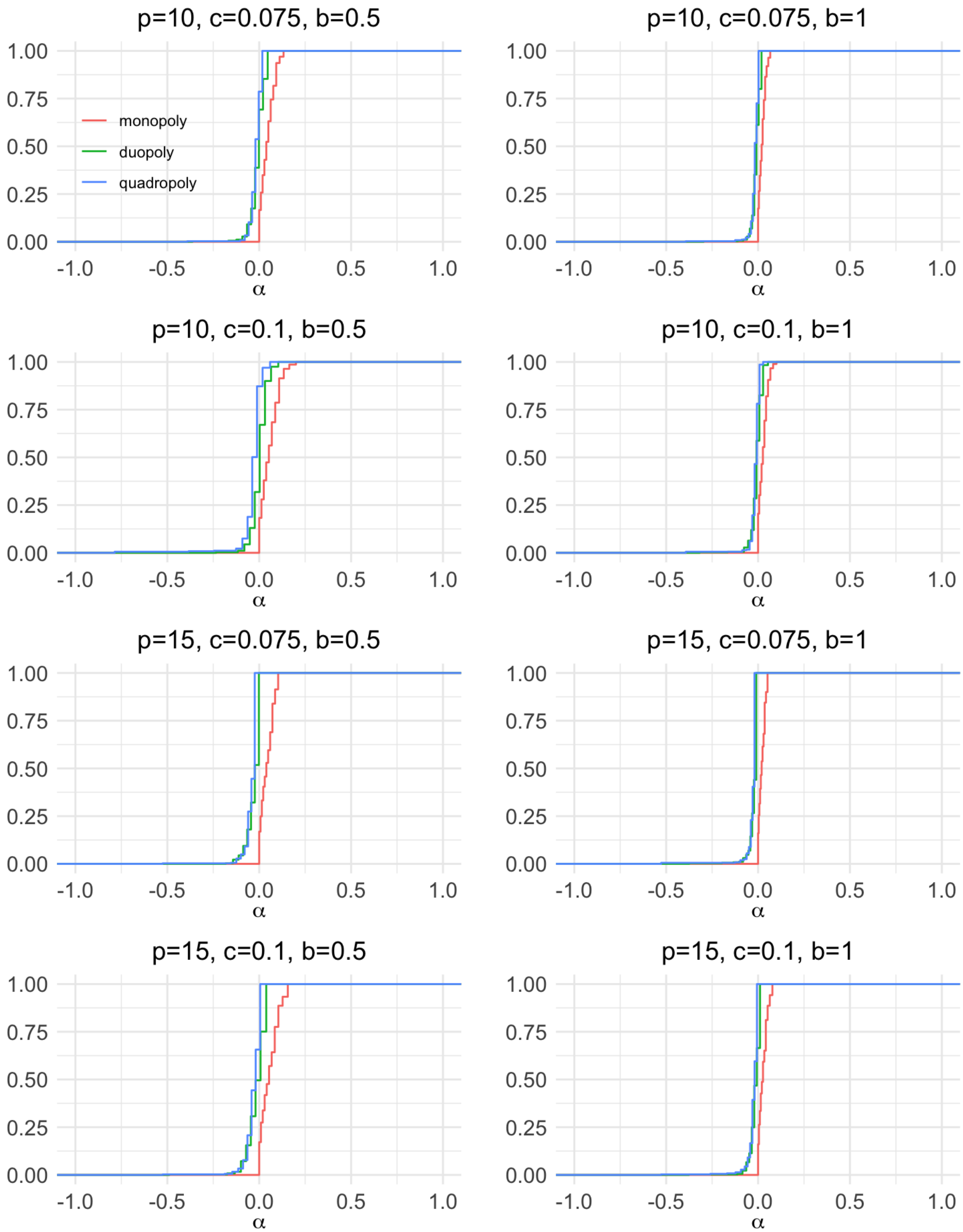

Figure 2: Distributions of estimated α in each market and in each incentive configuration under CARA with $r = 0.05$

4.2 Coefficient of absolute risk aversion $r = 0.15$

Table 5 presents the means of estimated α distributions in monopoly at $r = 0.15$. Table 6 reports the means and standard deviations of 24 altruism distributions normalized at the monopoly means. The difference between monopoly vs duopoly and duopoly vs quadropoly is smaller compared to the linear case but greater compared to the cases of $r = 0.05$ and $r = 0.10$. In Figure 3, we plot the 24 estimated altruism distributions at $r = 0.15$. Even after Bonferroni correction, we reject the equality of distributions at the significance level of 1% for most (101 out of 104) comparisons. We can reject the hypothesis at 5% for the comparison ($p = 10, c = 0.075, b = 0.5$) under duopoly vs ($p = 10, c = 0.075, b = 0.5$) under quadropoly (Bonferroni p-value is 0.036). After Bonferroni correction, we fail to reject hypotheses for the comparisons ($p = 10, c = 0.1, b = 1$) vs ($p = 15, c = 0.075, b = 0.5$) under monopoly and ($p = 15, c = 0.1, b = 0.5$) vs ($p = 10, c = 0.075, b = 0.5$) under monopoly, even at 10%.

Table 5: Normalized means and standard deviations of α distributions under CARA at $r = 0.15$

Incentive configurations	Estimated mean
$p = 10, c = 0.075, b = 0.5$	0.073
$p = 10, c = 0.075, b = 1$	0.036
$p = 10, c = 0.1, b = 0.5$	0.097
$p = 10, c = 0.1, b = 1$	0.047
$p = 15, c = 0.075, b = 0.5$	0.046
$p = 15, c = 0.075, b = 1$	0.023
$p = 15, c = 0.1, b = 0.5$	0.069
$p = 15, c = 0.1, b = 1$	0.033

Table 6: Normalized means and standard deviations of α distributions under CARA at $r = 0.15$

Incentive configurations	Monopoly		Duopoly		Quadropoly	
	mean	st. dev.	mean	st. dev.	mean	st. dev.
$p = 10, c = 0.075, b = 0.5$	0	0.073	-0.101	0.087	-0.121	0.069
$p = 10, c = 0.075, b = 1$	0	0.037	-0.061	0.053	-0.076	0.053
$p = 10, c = 0.1, b = 0.5$	0	0.109	-0.106	0.099	-0.177	0.141
$p = 10, c = 0.1, b = 1$	0	0.053	-0.066	0.068	-0.084	0.068
$p = 15, c = 0.075, b = 0.5$	0	0.045	-0.123	0.056	-0.147	0.057
$p = 15, c = 0.075, b = 1$	0	0.023	-0.076	0.044	-0.09	0.066
$p = 15, c = 0.1, b = 0.5$	0	0.078	-0.121	0.091	-0.148	0.076
$p = 15, c = 0.1, b = 1$	0	0.038	-0.071	0.054	-0.09	0.061

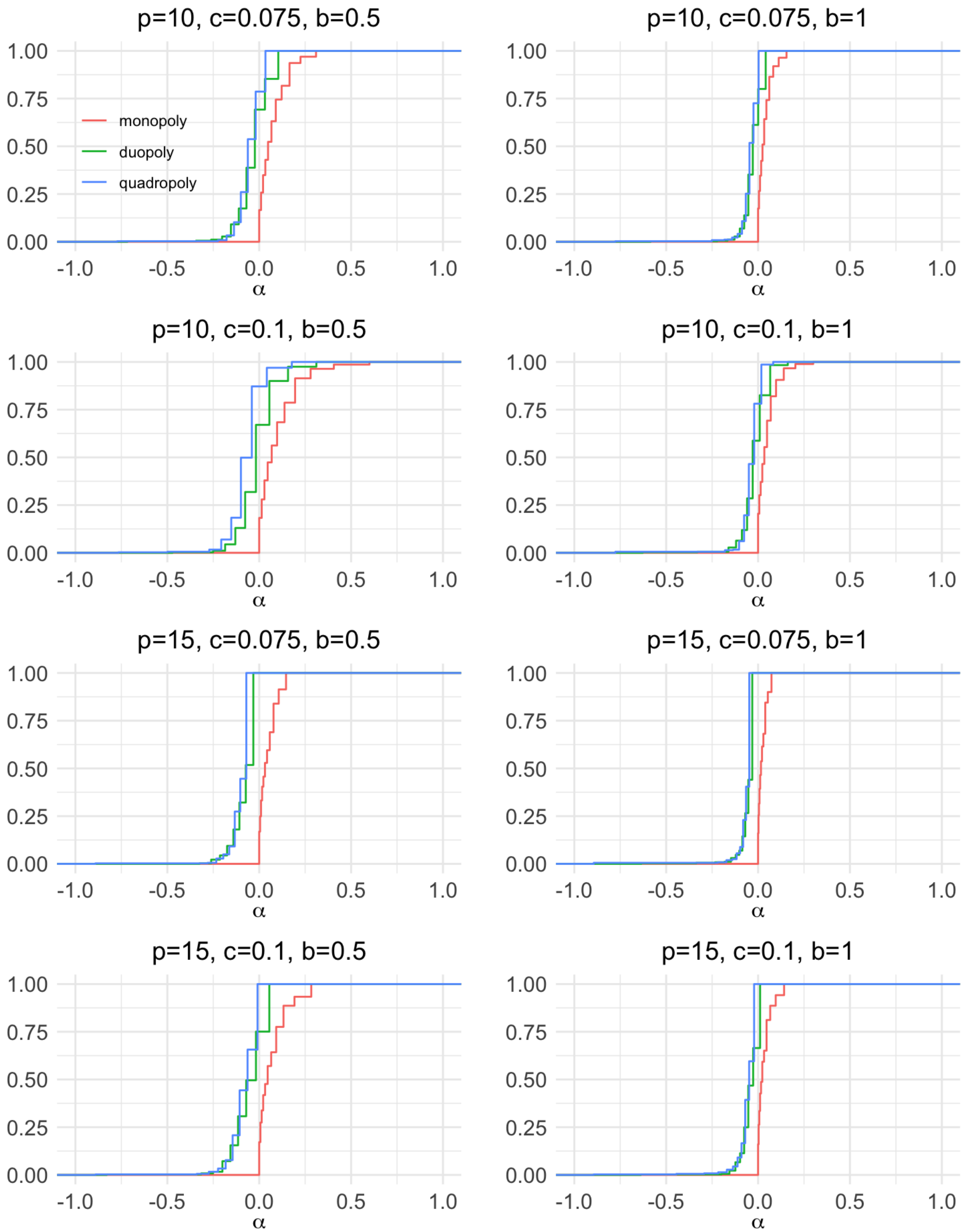

Figure 3: Distributions of estimated α in each market and in each incentive configuration under CARA with $r = 0.15$