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When less is more: Rationing and rent dissipation in stochastic contests ☆

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ABSTRACT

This paper shows how to maximize revenue when a contest is noisy. We consider a case where two or more contestants bid for a prize in a stochastic contest where all bidders value the prize equally. We show that, whenever a Tullock contest yields under-dissipation, the auctioneer's revenue can be increased by optimally fixing the number of tickets. In particular, in a stochastic contest with proportional probabilities, it is possible to obtain (almost) full rent dissipation. We test this hypothesis with a laboratory experiment. The results indicate that, as predicted, revenue is significantly higher in a lottery with rationing than in a standard lottery. On the other hand, an alternative rationing mechanism that does not limit total expenditures fails to increase revenue relative to a standard lottery.

1. Introduction

Gordon Tullock (1980) famously conceived rent seeking as a lottery where lobbyists compete for a prize held by a politician. The prize could be, for instance, a monopoly privilege, favorable legislation or a government contract, while lobbyists' bids consist of non-refundable investments that could take the form of campaign contributions, gifts or explicit briberies. Each lobbyist's probability of winning is equal to her lobbying expenditure divided by total lobbying expenditure. Similarly, lotteries are commonly employed to model, for example, rivalry and conflict (see, for example, Abbink et al., 2010), R&D tournaments, or market competition (Morgan et al., forthcoming).[1]

Lotteries are part of a class of contests described by a Tullock's success function. Within this class, each contest is defined by its degree of randomness. An all-pay auction is also a Tullock contest where randomness is reduced to zero. Like lotteries, all-pay auctions have also been used extensively to model, for instance, labor tournaments (e.g. Lazear and Rosen, 1981) or lobbying (see, for instance, Che and Gale, 1998). Which type of contest is a more appropriate description of, say, rent seeking activities or political competition is an interesting empirical question which has not been fully addressed yet. It is well known, however, that rents are fully dissipated in all-pay auctions, but not in lotteries.

Despite their inefficiency, lotteries are ubiquitous as fundraising mechanisms and their origins are so old that they can hardly be traced back in time. There exist virtually innumerable examples of lotteries used to raise funds for civic or

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[1] Moreover, a number of recent papers have explored the use of proportional contests as incentive mechanisms (Cason et al., 2010; Masters, 2005; Masters and Delbecq, 2008, among others). These tournaments have interesting applications as schemes to reward workers in firms or elicit effort among suppliers. It is worth noticing that, if contestants are risk neutral, proportional tournaments are isomorphic to a lottery.

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charitable purposes.[2] Just like national lotteries today help fund charitable causes, the Great Wall of China, the Republic of Milan's ongoing war against Venice in the fifteenth century, and the bridges, canals and fortifications of Burgundian and Dutch cities were all financed through public lotteries (see Welch, 2008). However, it would be wrong to exaggerate the importance of their public good component. As reported by the historian Evelyn Welch, "after the failure of the Milanese lottery to appeal to a sense of public duty, no Italian lottery (even those run by religious organizations) referred to either civic pride or spiritual devotion when encouraging ticket purchases. Buyers were simply enticed by the chance of winning wealth" (Welch, 2008, p. 97).

Indeed, although it is perhaps less known, it was equally frequent in the past for individuals or private institutions to hold lotteries and raffles to sell objects or raise revenue for private causes. In 1446, the widow of the Flemish painter Jan Van Eyck held one of the first recorded European lotteries to sell her late husband's expensive paintings, for which buyers could not be readily found. In Venice, during the sixteenth century, private lotteries were held daily for speculative reasons to sell objects as well as silver and gold. In seventeenth-century London, lotteries were commonly used to sell "books, maps and other goods" (Welch, 2008). The "running lotteries" of the Virginia Company are perhaps one of the most notorious examples of private lotteries. Between 1612 and 1621 the Virginia Company of London, a joint stock company, funded its enterprise through a series of local lotteries throughout England (Johnson, 1960).[3]

The question we address in this paper is how an auctioneer, or a fundraiser, can maximize revenue when the contest is noisy.[4] Under-dissipation in a Tullock game is caused by randomness, as the highest bidder does not win the prize with certainty. Note that in such contests there is no *ex ante* limit to how many tickets can be bought. Setting the number of tickets that can be purchased reduces randomness, as buying an extra ticket leaves less tickets available to the other contestants. We prove that, whenever under-dissipation occurs, the auctioneer can increase rent seeking expenditures by optimally fixing the number of tickets. In the case of a lottery it is possible to obtain (almost) full dissipation. This is why less is more: in equilibrium, setting a limit to total expenditures by rationing tickets leads to an increase in revenue relative to a standard contest.[5]

This mechanism is particularly appealing if agents are budget constrained. Consider for example an indivisible good. All bidders value the good Π, but no one can afford to spend more than $\omega < \Pi$. The seller could auction the object, obtaining a revenue of ω. Alternatively, she could use a lottery and, by appropriately setting the number of tickets, raise a revenue higher than ω. House raffles are an interesting example of rationed lotteries in the presence of budget constrained bidders.[6] In a house raffle, the home owner sells her property by selling a fixed number of lottery tickets to the public, the total value of the tickets being equal to the appraisal value of the house. Once all tickets are sold, one ticket is randomly drawn and the holder wins the property prize. Such lotteries are becoming more and more popular in the US, as well as in the UK, where they are attracting the attention of the media. Their popularity is mainly due to the credit constraints faced by the buyers, who are often unable to pay a price equal to the valuation of the house.[7]

In order to define a rationing scheme, we need a rule specifying how tickets are allocated when demand exceeds supply. We consider a lottery and assume that, when the capacity constraint is binding, each player is allocated a share of the tickets equal to her share of total demand. Given this allocation rule, the most intuitive scheme is one where bidders only pay for the tickets they actually receive. We call this mechanism *fixed price rationing*. It should be noted that, although this rationing scheme may lead to an increase in revenue relative to the standard lottery, it limits the maximum revenue a seller can potentially raise off equilibrium. We therefore also consider an alternative rationing scheme where bidders pay for the tickets they demand, while only receiving a share of the tickets equal to their share of total demand. We call this scheme *variable price rationing*. This mechanism shares the features of both fixed price rationing and a standard lottery. When demand is less than supply, it is identical to fixed price rationing, but when demand exceeds supply it works just like a standard lottery. Consequently, it does not limit potential revenue. We show that both rationing schemes lead to the same dissipation rate in equilibrium. However, while in fixed price rationing there is a unique equilibrium in dominant strategies, in variable price rationing there exists a continuum of multiple equilibria.

We test these theoretical predictions with a laboratory experiment, focusing on a case where two contestants bid for a prize with a common value in a stochastic contest with proportional probabilities. Using a between-subjects design,

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[2] A recent literature has analyzed the use of lotteries as fundraising mechanisms for the provision of public goods, both theoretically and through experiments (see Morgan, 2000; Morgan and Sefton, 2000; Goeree et al., 2005; Landry et al., 2006; Lange et al., 2007; Orzen, 2008; Schram and Onderstal, 2009; Corazzini et al., 2010, among others).

[3] The lotteries were extremely successful, so much so that the annual financial report for 1620 states that they brought to the company a profit of £7000. This was a very substantial sum, considering that the cost of furnishing one ship amounted at the time to about £791 (see Johnson, 1960).

[4] Although the literature on fundraising mechanisms has focused on situations where the contestants (significantly) value the public good, as we mentioned earlier, it is plausible to think of scenarios in which society values the project financed through their bids, but the bidders' valuation of it is actually zero.

[5] It should be observed that, by fixing supply, the auctioneer sets both a ceiling *and* a floor to the number of tickets. Although it is the presence of the floor that drives the result of (almost) full rent dissipation, we use the term rationing to emphasize the fact that the maximum number of tickets is fixed and there is an upper limit to potential revenue. This is in contrast to a standard lottery, where the maximum number of tickets is determined by demand and revenue is potentially unlimited.

[6] See, for example, http://winahouseraffles.com or http://www.usahomeraffle.com.

[7] A famous antecedent of these modern raffles is the case of the US President Thomas Jefferson, who attempted to sell his property, including the residence of Monticello, through a lottery with a fixed number of tickets. Only a series of unfortunate events prevented Jefferson from running the lottery (see Welch, 2008).

we test the hypothesis that expenditures are higher with either rationing mechanism than with the standard lottery. The results indicate that, as predicted by the theory, expenditures with fixed price rationing are significantly higher than in the standard lottery. However, contrary to the theoretical predictions, the variable-price rationing mechanism does not increase expenditures relative to the standard lottery. The results also reject the hypothesis of revenue equivalence for the two rationing schemes: expenditures are significantly higher with fixed price rationing than with variable price rationing. We interpret the findings for the variable-price rationing mechanism as reflecting strategic uncertainty. Individual behavior is consistent with this explanation.

Our work is related to a growing body of experimental research on rent seeking (Millner and Pratt 1989, 1991; Shogren and Baik, 1991; Davis and Reilly, 1998; Potters et al., 1998; Anderson and Stafford, 2003; Shupp, 2004; Schmitt et al., 2004, 2006; Bullock and Rutström, 2007; Herrmann and Orzen, 2008; Kong, 2008; Matros and Lim, 2009; Sheremeta, 2010, 2011, among others). With relatively few exceptions (see Shogren and Baik, 1991; Shupp, 2004; Schmitt et al., 2004), these experiments generally report higher rent seeking expenditures than predicted by the theory. Nevertheless, total expenditure is generally well below the value of the prize (see the review in Morgan et al., forthcoming). In the standard lottery treatment, we too find higher rent dissipation than predicted. However, expenditures are significantly higher under fixed price rationing.

There also exists a parallel theoretical literature that considers a very similar issue in the case of all-pay auctions (Che and Gale, 1998; Kaplan and Wettstein, 2006, among others). In a seminal paper, Che and Gale (1998) analyze a lobbying game between two lobbyists and a politician, and show that if the lobbyists have different valuations, then rents are not fully dissipated. They demonstrate that setting caps on *individual* bids can produce the perverse effect of increasing rent dissipation. Interestingly, in a subsequent paper, Fang (2002) shows that limiting individual bids does not increase rent dissipation in a lottery.

The remainder of the paper is organized as follows. Section 2 provides the theoretical framework. Section 3 describes the experimental design and procedures. Section 4 presents the results. Section 5 concludes.

2. Theory

Consider a Tullock contest where n risk-neutral players compete for a prize Π they all equally value. Players bid for the prize. Call b_j the bid of the generic player j. Player i's expected utility is given by

$$u_i(b_i) = \frac{b_i^{\rho}}{\sum_{j=1}^{n} b_j^{\rho}} \Pi - b_i, \tag{1}$$

where $\rho > 0$ and finite, while $\frac{b_i^{\rho}}{\sum_{j=1}^{n} b_j^{\rho}}$ represents i's probability of winning the prize. The case where $\rho = 1$ has been widely studied, and is typically interpreted as a lottery in which every player is entitled to a number of tickets equal to her bid. Once all players have submitted their bids, a ticket is randomly drawn and the holder wins the prize. A contest characterized by $\rho \neq 1$ can still be viewed as a raffle, although in this case a player who bids b obtains a number of tickets equal to b^{ρ}. Hence, when $0 < \rho < 1$ the contest exhibits decreasing returns, while $\rho > 1$ represents increasing returns to bidding.

If $\rho \leqslant \frac{n}{n-1}$ the contest has a symmetric pure strategy equilibrium.[8]

Proposition 1. *If $\rho \leqslant \frac{n}{n-1}$ there exists a symmetric pure strategy Nash equilibrium where each player bids $b^* = \frac{n-1}{n^2} \rho \Pi$ and the sum of all bids is equal to $\frac{n-1}{n} \rho \Pi$.*

Proof. See Appendix A. □

Notice from the previous proposition that if $\rho < \frac{n}{n-1}$ rents are not fully dissipated. Moreover, the more stochastic the contest the lower rent dissipation. If $\rho > \frac{n}{n-1}$ only mixed strategy equilibria exist. Although a complete characterization of the equilibria for the case $\frac{n}{n-1} < \rho < \infty$ is yet to be provided,[9] it is generally conjectured that such contests yield full dissipation of rents (see Baye et al., 1994, for the solution of the game when $n = 2$ and $\rho > 2$).

We modify the above game by fixing the total number of existing tickets, so that if some tickets remain unsold there is a positive probability that no one wins the prize. With a fixed number of tickets, a higher demand for tickets exerts a strategic effect, as less tickets will be left to a contestant's rivals. Thus, by rationing tickets randomness is reduced, producing an effect similar to an increase in the discriminatory parameter ρ. We show that, when rents are not fully dissipated with the standard contest ($\rho < \frac{n}{n-1}$), the auctioneer can raise a higher revenue by optimally fixing the number of tickets. We focus here on the case where $\rho = 1$, while in Appendix B we provide the solution for the generic case $\rho > 0$.

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[8] If $\rho = 1$ this equilibrium is unique (see Theorem 1 in Fang, 2002).

[9] If $\rho = \infty$ the contest becomes perfectly discriminatory, i.e. an all-pay auction. For a full characterization of its equilibria see Baye et al. (1996).

Call κ the fixed number of tickets, with $\kappa < \Pi$.[10] If agent i buys $b_i \leqslant \kappa$ tickets, her expected payoff is $\frac{b_i}{\kappa}\Pi - b_i$. Note that the marginal benefit of buying an extra ticket is always greater than the marginal cost. Hence, although the number of tickets a player can purchase will be subject to their availability, each agent would want to buy all the tickets. As a result, in equilibrium no ticket will remain unsold. Since κ can be set arbitrarily close to Π, rents can be (almost) fully dissipated.

We consider a simultaneous move game. We restrict the analysis to the case in which $\kappa \in (\frac{n-1}{n}\Pi, \Pi)$,[11] and we assume that each individual has the same endowment $\omega \geqslant \frac{\kappa}{n}$. Each agent submits a bid $b \in [0, \omega]$. Call B the sum of all bids and let $B_{-i} = \sum_{j \neq i}^{n} b_j$. Notice that it is necessary to define a rule specifying how to allocate the tickets in case total demand exceeds the fixed supply ($B > \kappa$). We apply the following rule. If total bids exceed κ, then each agent receives a share of the κ tickets equal to her share of the total demand ($\frac{b_i}{B}$). This implies that individual i's expected prize from bidding b_i, when the sum of all other players' bids is B_{-i}, is given by:

$$E[\Pi, \kappa, b_i, B_{-i}] = \begin{cases} \frac{b_i}{\kappa}\Pi & \text{if } B \leqslant \kappa, \\ \frac{b_i}{B}\Pi & \text{if } B > \kappa. \end{cases}$$

Finally, we need to define an expenditure rule specifying how much players pay for the tickets they purchase as a function of the tickets they demand, conditional on the other players' demands. Call $x(b_i \mid B_{-i})$ such function. Hence, a player's expected payoff is defined by

$$\omega + E[\Pi, \kappa, b_i, B_{-i}] - x(b_i \mid B_{-i}).$$

We consider two rationing mechanisms, defined by the different expenditure function they apply.

Definition 1. Fixed price rationing: $x(b_i \mid B_{-i})$ is equal to b_i if $B \leqslant \kappa$, while it is equal to $\frac{b_i}{B}\kappa$ if $B > \kappa$.

Definition 2. Variable price rationing: $x(b_i \mid B_{-i})$ is always equal to b_i.

With fixed price rationing agents only pay for the tickets they receive and the price of each ticket is equal to 1. With variable price rationing each player pays her own bid, independently of the number of tickets actually allocated to her. If total bids are less than or equal to κ, the price of each ticket is 1. But, if total demand exceeds supply, each agent receives $\frac{b_i}{B}\kappa$ tickets, which is equivalent to letting the price of each ticket vary to accommodate demand. Indeed, note that if $B > \kappa$ a ticket's price is equal $\frac{B}{\kappa}$.

As stated in the following proposition, with fixed price rationing there exists a unique equilibrium in dominant strategies.

Proposition 2. *With fixed price rationing there exists a unique Nash equilibrium in dominant strategies in which each player bids her whole endowment and total expenditure is equal to κ.*

Proof. See Appendix A. □

The next proposition shows that also with variable price rationing total expenditure in equilibrium is equal to κ. In this case though, there exist multiple equilibria. We provide a full characterization of the pure strategy equilibria of the game.

Proposition 3. *The complete set of pure strategy equilibria of the variable-price rationing mechanism is represented by the strategy profiles $\{b_1^*, b_2^*, \ldots, b_n^*\}$ such that $\sum_{i=1}^{n} b_i^* = \kappa$ and $\frac{\kappa(\Pi-\kappa)}{\Pi} \leqslant b_i^* \leqslant \omega$ $\forall i \in \{1, \ldots, n\}$. There always exists a symmetric equilibrium in which every player bids $\frac{\kappa}{n}$. Such equilibrium is unique if $\omega = \frac{\kappa}{n}$.*

Proof. See Appendix A. □

Note that variable price rationing resembles a coordination game in which players want to coordinate on a total demand equal to κ, although each one of them would prefer to demand as many tickets as possible, provided that B does not exceed κ. Due to this strategic uncertainty, the equilibrium prediction is clearly less robust than in fixed price rationing, where it is a dominant strategy to bid all the endowment. Yet, it is worth noting that while fixed-price rationing limits to κ the total revenue that can be extracted from the bidders, variable price rationing does not place any limit to the total revenue, albeit off equilibrium. This makes the latter mechanism directly comparable with a standard lottery, where the auctioneer can potentially earn a higher revenue than predicted.

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[10] As we show in Appendix B, if $\kappa > \Pi$ every player would bid zero. If $\kappa = \Pi$, in equilibrium total expenditures could take any value less than or equal to Π.

[11] Clearly, if $\kappa \leqslant \frac{n-1}{n}\Pi$ the auctioneer would raise a revenue lower than or equal to the amount raised with a standard lottery.

Table 1
Theoretical predictions for the experiment.

	LOT	RF	RV
Individual expenditure	400	600	600
Total expenditures	800	1200	1200
Dissipation rate	0.50	0.75	0.75

Note: $\Pi = 1600$, $\omega = 800$, $\kappa = 1200$. LOT = standard lottery. RF = fixed price rationing. RV = variable price rationing. Figures are expressed in points (experimental units). The prediction for RV at individual level (row 1) is expected expenditure.

3. The experiment

The experiment is designed to test the hypothesis that by exogenously setting the number of tickets in a lottery it is possible to increase contestants' expenditures. The experimental task is a standard rent seeking game as in Tullock (1980). We implement three treatments: a standard lottery, used as a benchmark, a lottery with fixed price rationing and a lottery with variable price rationing. In this section, we describe the design of the experiment, the hypotheses to be tested and the experimental procedures.

3.1. Baseline game

Two agents compete by expending resources (buying lottery tickets) to influence the probability of acquiring a given rent. Each session consists of 20 rounds. In each round, subjects have an endowment of 800 points and have to decide simultaneously how many lottery tickets they want to buy. Each ticket costs 1 point and subjects cannot bid more than their endowment. At the end of each round the computer selects randomly the winning ticket among all the existing tickets. The owner of the winning ticket wins a prize of 1600 points. In case no tickets are purchased, no one wins the prize. Actual earnings are determined on the basis of one round randomly selected at the end of the session.

3.2. Treatments

The experimental design is based on three treatments, implemented between subjects, aimed at comparing the effects of alternative allocation mechanisms that differ in the way participants can determine their probability of winning the prize (see Section 2 for details):

1. **Standard lottery** (LOT). Subjects can buy any number of tickets. At the end of each round the computer selects randomly the winning ticket *among all the tickets purchased*.
2. **Lottery with fixed price rationing** (RF). The total number of tickets is κ. If total bids (B) are not greater than κ, each subject receives a number of tickets equal to her bid (b_i) and wins with probability $\frac{b_i}{\kappa}$. If $B > \kappa$, each subject receives *a share of the κ tickets* equal to $\frac{b_i}{B}$, *pays only for the number of tickets she receives*, and wins with probability $\frac{b_i}{B}$.
3. **Lottery with variable price rationing** (RV). The total number of tickets is κ. If $B \leqslant \kappa$, each subject receives b_i tickets and wins with probability $\frac{b_i}{\kappa}$. If $B > \kappa$, each subject receives *a share of the κ tickets* equal to $\frac{b_i}{B}$, *pays for the number of tickets she demanded*, and wins with probability $\frac{b_i}{B}$.

3.3. Hypotheses

Table 1 presents the theoretical predictions for the three treatments in our experimental design, where we set the prize $\Pi = 1600$, the number of tickets under rationing $\kappa = 1200$, and the endowment of each subject $\omega = 800$. Individual endowments are set to be small relative to the prize in order to mimic a situation where subjects are budget constrained. The number of tickets under rationing (κ) is set at an intermediate level between the theoretical prediction for total expenditures in the standard lottery (800) and the value of the prize (1600). As a consequence, while in LOT total expenditures are 50% of the prize, in both RF and RV, total expenditures are 75% of the prize. Note also that the sum of individual endowments within a group is equal to the value of the prize, so that individual expenditures as a percentage of the endowment are equivalent to group-level expenditures as a percentage of the prize.

Defining μ_i as average expenditures in treatment i, the hypotheses to be tested can be stated as follows:

Hypothesis 1. Less is more. Expenditures are higher with either rationing mechanism than with the standard lottery:

$$H_0\colon\ \mu_{LOT} \geqslant \mu_{RF} \quad \text{vs} \quad H_1\colon\ \mu_{LOT} < \mu_{RF},$$
$$H_0\colon\ \mu_{LOT} \geqslant \mu_{RV} \quad \text{vs} \quad H_1\colon\ \mu_{LOT} < \mu_{RV}.$$

Hypothesis 2. Revenue equivalence. Expenditures are the same under fixed and variable price rationing:

$$H_0\colon\ \mu_{RF} = \mu_{RV} \quad \text{vs} \quad H_1\colon\ \mu_{RF} \neq \mu_{RV}.$$

3.4. Procedures

We implemented one session for each treatment, with 32 subjects participating in each session, for a total of 96 subjects. In each session, subjects were randomly assigned to a computer terminal at their arrival. In order to ensure public knowledge, instructions (see Appendix C) were distributed and read aloud. Moreover, to ensure understanding of the experimental design, sample questions were distributed and the answers privately checked and, if necessary, individually explained to the subjects.

A stranger matching mechanism, as in Andreoni (1988), was adopted in order to avoid strategic incentives. In each round, subjects were randomly and anonymously rematched in pairs. At the end of each round, subjects were informed of their own payoff, given by the initial endowment, minus the expenditure for buying the tickets, plus the prize if won. At the end of the last round, subjects were informed of their total payoff for each of the twenty rounds, and of the actual earnings in points and Euros determined on the basis of a randomly selected round. They were then asked to answer a short questionnaire on the understanding of the experiment and socio-demographic information, and were paid in private using an exchange rate of 100 points per Euro.

Subjects earned 14.5 Euro on average for sessions lasting about 50 minutes, including the time for instructions. Participants were undergraduate students of Economics recruited by e-mail using a list of voluntary potential candidates. The experiment took place in March 2010 in the Experimental Economics Lab of the University of Milan Bicocca. The experiment was computerized using the z-Tree software (Fischbacher, 2007).

4. Results

This section presents the experimental results. We start with a descriptive analysis of the main features of the data in the three treatments. We then present formal tests of the theoretical predictions. Finally, in order to interpret treatment effects, we compare behavior at individual level.

4.1. Overview

We collected observations for 96 subjects (64 males), randomly assigned to each of the 3 sessions-treatments. Average age and year of enrollment are 22.2 (range 20–25, s.d. 1.5) and 2.9 (range 1–6, s.d. 0.9), respectively. About 55% of the subjects have a non-vocational high school diploma. A university degree is reported as the highest educational attainment by 21.9 and 11.5 percent of the subjects for father and mother, respectively. Differences in gender composition across sessions are not significant (Pearson's $\chi^2_2 = 2.9$, $p = 0.23$). Similar results apply to age ($\chi^2_{10} = 9.5$, $p = 0.48$), year of enrollment ($\chi^2_{10} = 14.5$, $p = 0.16$), high school diploma ($\chi^2_8 = 7.5$, $p = 0.49$) and parental education (father: $\chi^2_8 = 5.9$, $p = 0.65$, mother: $\chi^2_8 = 9.96$, $p = 0.27$). Overall, the socio-demographic characteristics of the subjects are comparable across sessions.

Fig. 1 compares overall mean and median relative expenditures (as a percentage of the endowment) for each of the three treatments.[12] Mean relative expenditures are 55.1% in LOT, 64.9% in RF and 49.1% in RV. Median relative expenditures are 50% and 75%, respectively, in LOT and RF. These figures are strikingly consistent with the theory. Contrary to the theoretical predictions, median relative expenditures in RV are the same as in the standard lottery (50%). Over successive rounds, average expenditures are relatively stable in all treatments, displaying only a slight overall decline.[13]

Overall, these descriptive results indicate that, as predicted by the theory, while the standard lottery produces substantial under-dissipation, fixed price rationing provides an effective mechanism to increase revenue. On the other hand, contrary to the theoretical predictions, the variable-price rationing mechanism does not increase expenditures relative to the standard lottery.

4.2. Treatment effects

In order to assess the significance of the treatment effects, it is necessary to take into account that observations are not independent between subjects, given the feedback received at the end of each round and the stranger matching mechanism. We thus estimate the average difference in expenditures between the relevant treatment pairs, while conditioning on the information available to the subjects. Since subjects are not informed about their rivals' expenditures, but only about their own payoff as a result of the outcome of the contest, we use the following specification

$$b_{it} = \alpha + \delta T + \sum_{j=1}^{k} \beta_j \pi_{i,t-j} + \varepsilon_{it}, \qquad (2)$$

[12] Note that in presenting the results we refer to individual-level expenditures as a percentage of the endowment. Given the parameter calibration ($N = 2$, $\omega = 800$, $\Pi = 1600$), this is equivalent to referring to group-level expenditures as a percentage of the prize.

[13] In LOT, average relative expenditures start above the theoretical predictions, but gradually converge to 50% over successive rounds. In RF, average expenditures are relatively stable and slightly below the theoretical prediction throughout the session. In RV, average expenditures are substantially lower than the 75% prediction and declining over rounds.

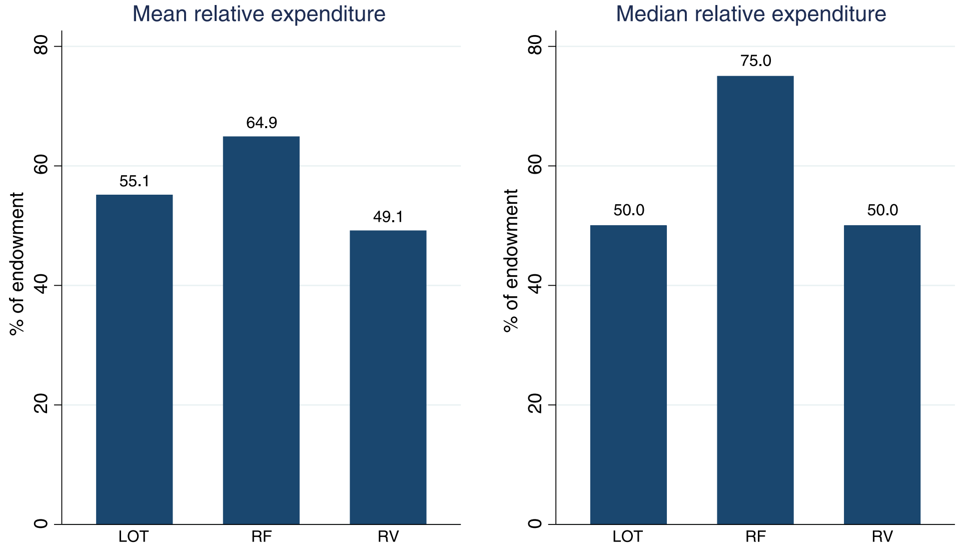

Fig. 1. Overall expenditures, by treatment.

Table 2
Significance of treatment effects on expenditures.

	(1)	(2)	(3)	(4)	(5)	(6)
RF–LOT	11.36* (5.91)			10.88* (5.82)		
RV–LOT		−0.68 (5.81)			0.68 (5.82)	
RF–RV			12.92** (4.90)			16.41** (4.40)
Prize won	Yes	Yes	Yes	Yes	Yes	Yes
Other's expenditure	No	No	No	Yes	Yes	Yes
R^2	0.08	0.09	0.15	0.08	0.11	0.19
Observations	1152	1152	1152	1152	1152	1152

Note: Dependent variable: individual expenditure in round t. OLS estimates based on the relevant pair of treatments: RF and LOT $(1, 4)$, RV and LOT $(2, 5)$, RF and RV $(3, 6)$. Models (1) to (6) include two lags of a dummy variable for the outcome of the contest. Models (4) to (6) also include two lags of the rival's expenditure. Robust standard errors, reported in parentheses, are adjusted for clustering on individuals.

* Level of significance $p < 0.05$ for the relevant hypotheses, as described in Section 3.3.

** Level of significance $p < 0.01$ for the relevant hypotheses, as described in Section 3.3.

where b_{it} is subject i's expenditure in period t, T is a dummy variable for the relevant treatment, π_{it} is a dummy indicating whether subject i won the prize in round t, k is the number of lags, and ε_{it} is an idiosyncratic error term. In order to account for dependence within subjects over successive rounds, standard errors are adjusted for clustering on individuals.[14]

It should be observed, however, that the feedback received by the subjects may indirectly give them information about the expenditures of other subjects. In the RF treatment, in particular, in the case that total demand exceeds supply, feedback about own payoff and expenditure on tickets indirectly reveals the number of tickets sought by the rival. When total demand does not exceed supply, the feedback reveals an upper bound on rival's demand. Therefore, in order to account for the dependence possibly arising from such indirect information, we also consider a second specification that includes lags of rivals' expenditures among the explanatory variables, as if they were directly observable by the subjects, in addition to outcomes of the contest:

$$b_{it} = \alpha + \delta T + \sum_{j=1}^{k} \beta_j \pi_{i,t-j} + \sum_{j=1}^{k} \gamma_j b_{\tilde{\imath},t-j} + \varepsilon_{it}, \tag{3}$$

where $b_{\tilde{\imath},t}$ is the expenditure of the subject interacting with subject i in period t. Eqs. (2) and (3) are estimated for each of the relevant treatment pairs (RF–LOT, RV–LOT, RF–RV) setting $k = 2$.

Table 2 reports the results. Treatment effects based on Eq. (2) are reported in columns (1) to (3). The difference in expenditures between RF and LOT is large and strongly significant ($p < 0.03$). The estimated difference between RV and

[14] We use OLS with standard errors adjusted for clustering on individuals, rather than a random effect estimator, since the former approach is less restrictive, as it allows for arbitrary correlation within subjects and the form of this correlation can vary from subject to subject.

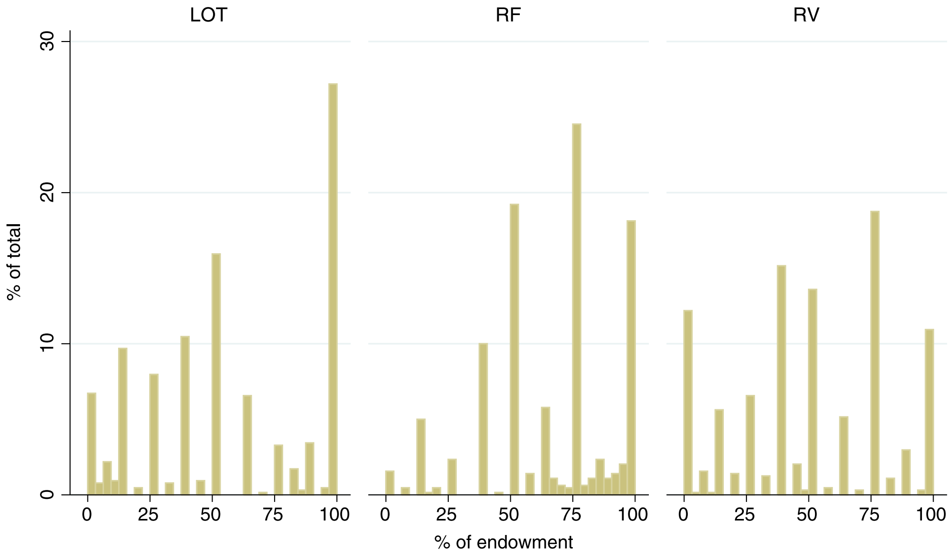

Fig. 2. Distribution of individual expenditures, all rounds.

LOT, instead, is not statistically significant ($p < 0.46$). In the comparison between the two rationing schemes, the positive difference between RF and RV is strongly statistically significant ($p < 0.01$). It should be noted that these results are not sensitive to the selected number of lags. When $k = 4$, for example, p-values for the corresponding tests are 0.02, 0.24, and 0.02 for RF–LOT, RV–LOT and RF–RV, respectively. Columns (4) to (6) report the corresponding estimation results based on Eq. (3). All the test results are virtually unchanged: conditioning on both the information directly available to the subjects and the unobserved choices of interacting subjects, expenditures are significantly higher in RF than in both LOT ($p < 0.03$) and RV ($p < 0.00$). On the contrary, there are no significant differences between RV and LOT ($p < 0.45$). As above, the test results are not sensitive to the number of lags. When $k = 4$, p-values for the relevant tests are 0.02, 0.24, and 0.01 for RF–LOT, RV–LOT and RF–RV, respectively. Overall, the results are robust across alternative specifications.

Summing up, the main results can be stated as follows:

Result 1. Expenditures in the lottery with fixed price rationing are significantly higher than in the standard lottery.

Result 2. The variable-price rationing mechanism does not increase expenditures relative to the standard lottery.

Result 3. Expenditures with fixed price rationing are significantly higher than with variable price rationing.

4.3. Individual behavior

In order to interpret the treatment effects described above, we now turn to individual choices. Fig. 2 compares the distribution of individual expenditures for the three treatments. In LOT, 15.9 percent of the subjects spend half of their endowment, as predicted by theory. Although a relatively large fraction of the subjects spend their whole endowment (27.2 percent), about 41 percent spend less than half of their endowment. In RF, the expenditure predicted by the theory (0.75) is indeed the modal value (24.1 percent). The high overall expenditures in this treatment are also explained by a large fraction of subjects spending their whole endowment (18.1 percent) or half their endowment (19.1 percent). Interestingly, only a fifth of the subjects spend less than 50 percent of their endowment. The comparison with the distribution for LOT indicates that the fixed-price rationing mechanism is indeed effective in discouraging low expenditures. In RV, the theoretical prediction of 0.75 represents the modal value (18.1 percent). However, relatively few subjects spend their whole endowment (10.9 percent) or half of it (13.6 percent), whereas 46.4 percent of the subjects spend less then half of their endowment. In particular, RV is characterized by a much higher fraction of zero expenditure (8.3 percent) than either LOT or RF (2.8 and 1.1 percent, respectively).

It should be observed that in RF actual expenditures are different from original bids in all the pair-round cases where the constraint on the supply of tickets is binding. This implies that the 0.75 modal value for individual relative expenditures for RF in Fig. 2 may comprise both actual bids of 0.75 and higher bids rationed ex post. This also explains the clustering of density around 0.75 for expenditures in RF. In order to assess strategic behavior before the effect of rationing, Fig. 3 displays the distribution of individual *bids* (tickets demanded) over all rounds for the fixed-price rationing mechanism. Interestingly, about 40 percent of the subjects bid their whole endowment, as predicted, as opposed to 27.2 and 10.9 percent in LOT or

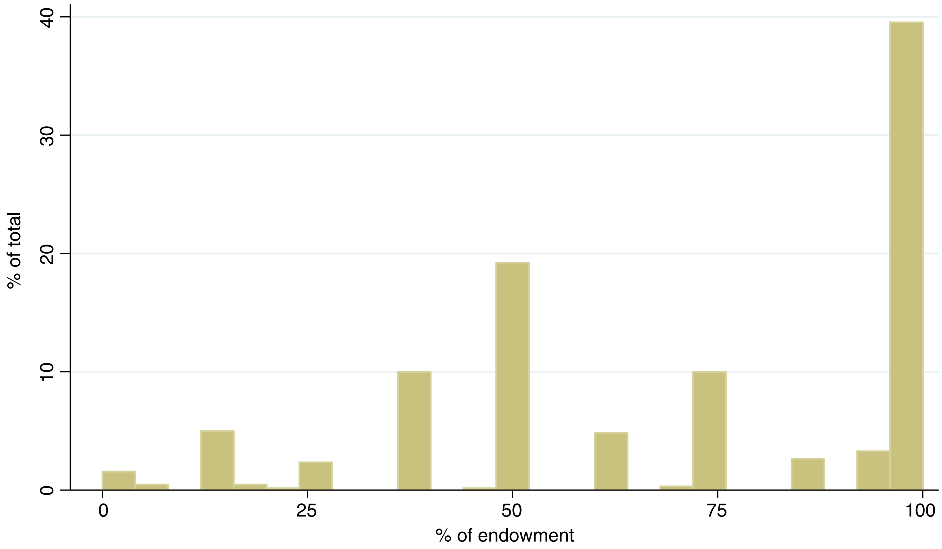

Fig. 3. Distribution of individual bids: fixed price rationing, all rounds.

RV, respectively. An additional 10 percent of the subjects bid 0.75 of their endowment. Overall, the distribution of individual bids provides further support to the theoretical predictions for fixed price rationing.

The results for the variable-price rationing mechanism, instead, differ substantially from the theoretical predictions. We interpret this discrepancy as the effect of strategic uncertainty.[15] The existence of a continuum of multiple equilibria in RV determines uncertainty about the actions and beliefs, and beliefs about the beliefs, of other subjects. This may result in lower individual expenditures relative to RF, where there is a unique equilibrium in dominant strategies.[16] Although theory does not provide clear predictions for coordination games with multiple equilibria, several experiments have shown that, in repeated interactions, subjects' may be able to coordinate on an equilibrium that depends on factors such as group size, payoff function, dispersion of information and experience (Van Huyck et al., 1990, 1991; Berninghaus and Erhard, 1998, 2001; Heinemann et al., 2004). In our experimental design, however, the coordination game that subjects play in the RV treatment is particularly difficult to solve, due to the random matching in each round and the lack of feedback about other subjects' bids.

The effect of strategic uncertainty is consistent with the evidence reported above that there is a relatively large fraction of zero and low expenditures in RV. This finding, however, is also consistent with alternative explanations. For example, the higher complexity of the RV mechanism, relative to RF, would also imply a higher fraction of low expenditures, as subjects decide to stay away from an incentive mechanism they are less familiar with, or do not fully understand. In order to assess the specific role played by strategic uncertainty, we examine the variability of individual choices over successive rounds. If the differences between observed choices and theoretical predictions in RV are caused by strategic uncertainty, we should observe a higher variability of individual bids over rounds in RV than in RF. This hypothesis is indeed supported by the data. The individual-level standard deviation of bids over the 20 rounds is 14.5 and 18.8 on average in RF and RV, respectively. We conclude that strategic uncertainty, enhanced by random matching and limited feedback, is the most likely explanation of the deviation from theoretical predictions for the variable-price rationing mechanism.

5. Conclusions

In this paper we have shown that, whenever a stochastic contest yields under-dissipation of rents, it is possible to increase the auctioneer's revenue by optimally fixing the number of tickets. In particular, in the case of proportional probabilities, it is possible to obtain (almost) full rent dissipation. We characterized the theoretical properties of two alternative rationing schemes, where the price of each ticket is either fixed or variable. We tested the theoretical predictions with a laboratory experiment where two contestants bid for a prize they equally value in a stochastic contest with proportional probabilities.

The results indicate that, as predicted by the theory, less is more: relative to a standard lottery, revenue is significantly higher in a lottery where tickets are rationed and their price is fixed, so that potential revenue is limited. In addition,

[15] As in Brandenburger (1996), strategic uncertainty is defined as uncertainty concerning the purposeful behavior of players in an interactive decision situation. See also Heinemann et al. (2009).

[16] As noted above, the variable-price rationing mechanism can be viewed as a coordination game where players want to coordinate on a total demand equal to κ, although each one of them would prefer to demand as many tickets as possible, provided that B does not exceed κ.

contrary to the theoretical predictions, a rationing mechanism with variable price, where potential revenue is unlimited, does not increase revenue relative to a standard lottery. We interpreted this finding as reflecting the effect of strategic uncertainty. While fixed price rationing has a unique equilibrium in dominant strategies, under variable price rationing there exists a continuum of multiple equilibria, thus introducing a coordination problem for the contestants. Individual behavior is consistent with this explanation.

Appendix A. Proofs

Proof of Proposition 1. Differentiating expression (1) with respect to b_i we obtain the following first order condition

$$\frac{\rho \Pi b_i^{\rho-1} \sum_{j\neq i}^n b_j^\rho}{(b_i^\rho + \sum_{j\neq i}^n b_j^\rho)^2} - 1. \tag{4}$$

Notice that $b_i^\rho + \sum_{j\neq i}^n b_j^\rho \neq 0$ in equilibrium, otherwise an individual could bid ε arbitrarily small and win the prize with certainty. We set (4) equal to zero and, as we are looking for a symmetric equilibrium, we replace $\sum_{j\neq i}^n b_j^\rho$ with $(n-1)b_i^\rho$, obtaining

$$\frac{1}{b_i}\frac{(n-1)}{n}\rho\frac{\Pi}{n} = 1. \tag{5}$$

Solving (5) for b_i we derive the candidate equilibrium $b^* = \frac{n-1}{n^2}\rho\Pi$. For this to be an equilibrium it must be the case that no one has an incentive to deviate when all other players are bidding b^*, thus requiring that

$$u_i\big(b_i \mid b_j = b^* \ \forall j \neq i\big) = \frac{b_i^\rho}{b_i^\rho + (n-1)(b^*)^\rho}\Pi - b_i \tag{6}$$

has a global maximum at $b_i = b^*$. Let $v(b_i) = u_i(b_i \mid b_j = b^* \ \forall j \neq i)$. The second derivative of $v(b_i)$ is equal to

$$\frac{\partial^2 v(b_i)}{\partial b_i^2} = \frac{\rho\Pi(n-1)(b^*)^\rho b_i^{\rho-2}}{[(n-1)(b^*)^\rho + b_i^\rho]^3}\big[(\rho-1)(n-1)\big(b^*\big)^\rho - (\rho+1)b_i^\rho\big].$$

The above expression is negative at $b_i = b^*$, and therefore $v(b_i)$ has a local maximum at b^*, if and only if $\rho < \frac{n}{n-2}$. Thus we know that b^* can only be an equilibrium when $\rho < \frac{n}{n-2}$. Notice that $\frac{\partial^2 v(b_i)}{\partial b_i^2} < 0 \ \forall b_i$ if $\rho < 1$. Similarly, if $\rho = 1$ we have $\frac{\partial^2 v(b_i)}{\partial b_i^2} < 0 \ \forall b_i > 0$, while $\frac{\partial^2 v(b_i)}{\partial b_i^2} = 0$ for $b_i = 0$. Hence $v(b_i)$ has a global maximum at b^* if $\rho \leqslant 1$. Consider now the case $\rho > 1$. The function $v(b_i)$ has an inflection point at $\tilde{b} = [\frac{(\rho-1)(n-1)}{\rho+1}]^{\frac{1}{\rho}} b^*$, being convex for $b_i < \tilde{b}$ and concave for $b_i > \tilde{b}$. As a consequence, $v(b^*) \geqslant v(0)$ is a sufficient condition for b^* to be a global maximum point. From (6) we can see that $v(b^*) \geqslant v(0) \ \forall \rho \leqslant \frac{n}{n-1}$, thus proving that b^* is an equilibrium if and only if $\rho \leqslant \frac{n}{n-1}$. □

Proof of Proposition 2. It is easy to show that bidding ω is a dominant strategy for this game. Let us first consider the case $\omega + B_{-i} \leqslant \kappa$. An individual's expected payoff from bidding ω is equal to $\frac{\omega}{\kappa}(\Pi - \kappa)$, while, if she bids $z < \omega$, her expected utility is $\frac{z}{\kappa}(\Pi - \kappa)$. Since $\kappa < \Pi$, the latter is strictly less than the former.

Suppose now that $\omega + B_{-i} > \kappa$. Clearly, if $B_{-i} = 0$ then bidding $z < \omega$ would either guarantee the same utility $\Pi - \kappa$, if $z \geqslant \kappa$, or a lower expected payoff otherwise. Hence suppose $B_{-i} > 0$. The expected payoff from bidding ω is equal to $W = \frac{\omega}{\omega + B_{-i}}(\Pi - \kappa)$. Vice versa a player's expected utility from bidding $z < \omega$ is represented either by $X = \frac{z}{z + B_{-i}}(\Pi - \kappa)$, if $z + B_{-i} > \kappa$, or by $Y = \frac{z}{\kappa}(\Pi - \kappa)$ if $z + B_{-i} \leqslant \kappa$.

Let us compare W and X. Their difference is given by

$$W - X = \frac{B_{-i}(\omega - z)(\Pi - \kappa)}{(\omega + B_{-i})(z + B_{-i})} > 0,$$

which means that bidding ω strictly dominates any lower bid z when $z + B_{-i} > \kappa$.

When $z + B_{-i} \leqslant \kappa$, we have to study the sign of $W - Y$, given by

$$\begin{aligned} W - Y &= \frac{\omega}{\omega + B_{-i}}(\Pi - \kappa) - \frac{z}{\kappa}(\Pi - \kappa) \\ &= (\Pi - \kappa)\frac{\omega(\kappa - z) - zB_{-i}}{(\omega + B_{-i})\kappa}. \end{aligned}$$

The above expression is greater than zero if $\omega > \frac{zB_{-i}}{(\kappa - z)}$. Since $B_{-i} \leqslant \kappa - z$, this inequality is always true. This proves that bidding ω is a dominant strategy. Finally, as we are assuming that $\omega \geqslant \frac{\kappa}{n}$, total expenditure is equal to κ. □

Proof of Proposition 3. We first show that in equilibrium the sum of all bids cannot be strictly less or greater than κ. If $b_i + B_{-i} < \kappa$ then player i would have an incentive to increase her bid from b_i to $\kappa - B_{-i}$, since the marginal benefit is greater than the marginal cost. If $b_i + B_{-i} > \kappa$ player i's utility is equal to $\Pi \frac{b_i}{b_i + B_{-i}} - b_i$, which is the payoff of a standard Tullock contest. Since we know that in a Tullock game in equilibrium $B = \frac{n-1}{n}\Pi$, and we assumed that $\frac{n-1}{n}\Pi < \kappa < \Pi$, it follows that B cannot be greater than κ.

It remains to explore the case $B = \kappa$. In order for a strategy profile $\{b_1, b_2, \dots, b_n\}$, with $\sum_{i=1}^n b_i = \kappa$, to be an equilibrium we have to verify under what conditions no player has an incentive to deviate. Clearly, an agent who is submitting a positive bid has no incentive to decrease it. However, it is possible that a player may be better off by increasing her bid. Recall that, keeping the strategies of the other agents constant, if i raises her bid to $\hat{b}_i > b_i$ her payoff is $\Pi \frac{\hat{b}_i}{\hat{b}_i + B_{-i}} - \hat{b}_i$. Differentiating i's payoff with respect to $\hat{b}_i$ we obtain

$$\Pi \frac{B_{-i}}{(\hat{b}_i + B_{-i})^2} - 1.$$

Setting the above expression equal to zero and solving for $\hat{b}_i$ we obtain i's best response function

$$\hat{b}_i = \sqrt[2]{\Pi B_{-i}} - B_{-i}.$$

This means that i will not have an incentive to raise her bid above b_i provided that $b_i \geqslant \sqrt[2]{\Pi B_{-i}} - B_{-i}$. Since $\sum_{i=1}^n b_i = \kappa$, we can substitute B_{-i} with $\kappa - b_i$ and, rearranging, we obtain

$$b_i \geqslant \frac{\kappa(\Pi - \kappa)}{\Pi}.$$

It follows that the complete set of pure strategy equilibria for this game is represented by the strategy profiles $\{b_1^*, b_2^*, \dots, b_n^*\}$ such that $\sum_{i=1}^n b_i^* = \kappa$ and $\frac{\kappa(\Pi-\kappa)}{\Pi} \leqslant b_i^* \leqslant \omega\ \forall i \in \{1, \dots, n\}$. Notice that the symmetric equilibrium in which every player bids $\frac{\kappa}{n}$ is always an element of this set, and it is the unique equilibrium if $\omega = \frac{\kappa}{n}$. □

Appendix B. Solution for a generic ρ

Suppose that agents buy tickets sequentially, subject to their availability.[17] If an agent buys $b^\rho \leqslant \kappa$ tickets, she pays b and her expected payoff is defined by

$$\frac{b^\rho}{\kappa}\Pi - b. \tag{7}$$

Proposition 4. *If $\rho < 1$ the auctioneer optimally sets $\kappa = (\rho\Pi)^\rho$, she sells all the tickets and raises a revenue equal to $\rho\Pi$. If $\rho \geqslant 1$ the auctioneer sets κ arbitrarily close to Π^ρ, selling all the tickets and generating a revenue equal to $\kappa^{\frac{1}{\rho}}$; hence, if $\rho \geqslant 1$, rents can be (almost) fully dissipated.*

Proof. Suppose $\rho \neq 1$. Differentiating (7) with respect to b and setting it equal to zero we obtain

$$b^* = \left(\frac{\kappa}{\rho\Pi}\right)^{\frac{1}{\rho-1}}.$$

The second derivative of (7) is equal to

$$\rho(\rho-1)b^{\rho-2}\frac{\Pi}{\kappa}. \tag{8}$$

Consider first the case where $\rho < 1$. Expression (8) is negative for any $b > 0$, indicating that the function has a global maximum at b^*. Notice that $(b^*)^\rho > \kappa$ if $\kappa < (\rho\Pi)^\rho$ and $(b^*)^\rho = \kappa$ for $\kappa = (\rho\Pi)^\rho$. As it is not possible to buy more than κ tickets, if $\kappa \leqslant (\rho\Pi)^\rho$ each agent would want to buy all of the tickets, resulting in a revenue equal to $\kappa^{\frac{1}{\rho}}$. Hence, in the range $\kappa \in [0, (\rho\Pi)^\rho]$ revenue is maximized by setting $\kappa = (\rho\Pi)^\rho$. If $\kappa > (\rho\Pi)^\rho$ then $(b^*)^\rho < \kappa$ and each agent would want to buy $(b^*)^\rho$ tickets. Let $\bar{n} = \frac{\kappa}{(b^*)^\rho}$. If $\bar{n}$ is an integer total revenue would be at most equal to $\bar{n}b^*$; if $\bar{n}$ is not an integer total revenue cannot be greater than $\hat{n}b^* + [\kappa - \hat{n}(b^*)^\rho]^{\frac{1}{\rho}}$, where $\hat{n}$ is the lower integer closest to $\bar{n}$. Since $\rho < 1$, it is easy to show that $\hat{n}b^* + [\kappa - \hat{n}(b^*)^\rho]^{\frac{1}{\rho}} < \bar{n}b^*$, which implies that total revenue is bounded from above by $\bar{n}b^*$. Finally, notice that $\bar{n}b^* = \rho\Pi$. Hence, even if the number of bidders was large enough for all the tickets to be sold, the overall revenue would be at most equal to the revenue raised by setting $\kappa = (\rho\Pi)^\rho$.

[17] This is equivalent to a mechanism where all agents simultaneously demand tickets, the auctioneer randomly orders them and supplies them one after the other.

Let us now consider the case $\rho > 1$. Expression (8) is positive for any $b > 0$, which means that the function is convex and has a global minimum at b^*. Notice that expression (7) is positive if and only if $b > (\frac{\kappa}{\Pi})^{\frac{1}{\rho-1}}$, which implies that an agent would not buy less than $(\frac{\kappa}{\Pi})^{\frac{\rho}{\rho-1}}$ tickets. Moreover, since the function is convex, an individual maximizes her payoff by buying all the tickets, provided that this gives a positive utility. This condition is satisfied if $\kappa^{\frac{1}{\rho}} > (\frac{\kappa}{\Pi})^{\frac{1}{\rho-1}}$, which implies $\kappa < \Pi^{\rho}$. It follows that each agent wants to buy κ tickets if $\kappa < \Pi^{\rho}$, she is indifferent between buying all the tickets and not buying any if $\kappa = \Pi^{\rho}$, and she buys no tickets when $\kappa > \Pi^{\rho}$. As a consequence, the auctioneer sets κ arbitrarily close to Π^{ρ}, raising a revenue equal to $\kappa^{\frac{1}{\rho}}$.

Finally, consider the case $\rho = 1$. The marginal benefit of buying an extra ticket is $\frac{\Pi}{\kappa}$, while the marginal cost is equal to 1. If $\kappa < \Pi$ the marginal benefit is always greater than the marginal cost and each agent would want to buy all the tickets. If $\kappa > \Pi$ the marginal cost always exceeds the marginal benefit and no one would want buy any tickets. If $\kappa = \Pi$ the marginal benefit is identical to the marginal cost and each agent is indifferent between buying a positive number of tickets and bidding zero. Hence, as in the case of $\rho > 1$, the auctioneer sets κ arbitrarily close to Π, raising a revenue equal to κ. □

If $\rho < 1$, the revenue raised by setting $\kappa = (\rho\Pi)^{\rho}$ is higher than the amount obtained through the standard lottery $(\frac{n-1}{n}\rho\Pi)$. If instead $\rho \geqslant 1$, rents can be (almost) fully dissipated. Therefore, when $\rho < \frac{n}{n-1}$, by appropriately rationing tickets it is possible to obtain a higher revenue than with a standard lottery.

Appendix C. Experimental instructions

[In italics parts that are common across treatments]

Welcome. Thanks for participating in this experiment. If you follow the instructions carefully and make good decisions you can earn an amount of money that will be paid to you in cash at the end of the experiment. During the experiment you are not allowed to talk or communicate in any way with other participants. If you have any questions raise your hand and one of the assistants will come to assist you.

General rules

- *There are* 32 *subjects participating in this experiment.*
- *The experiment will consist of* 20 *rounds.*
- *In each round you will interact in a group of* 2 *with another participant selected randomly and anonymously by the computer.*
- *In each round each participant will be assigned an endowment of* 800 *points. You will make decisions that will determine the number of points you can earn.*
- *At the end of each round the computer will display your payoff in points.*
- *When the* 20 *rounds are completed, one round will be randomly chosen by the computer. The number of points that you have obtained in the selected round will be converted in euros at a rate of* 100 *points per euro and the resulting amount will be privately paid to you in cash.*

How earnings are determined

Treatment 1 (Standard Lottery)

- In each round, you and the other participant will play a two-person lottery. The lottery prize is 1600 points. You and the other participant will be given the chance to purchase lottery tickets at 1 point per ticket. As you purchase tickets, your point endowment will be reduced by the value of the tickets purchased.
- At the end of each round the computer will select randomly the winning ticket among all the tickets purchased. The owner of the winning ticket wins the prize.
- Thus, your probability of winning is given by the number of points you purchase divided by the total number of tickets purchased by you and the other participant in your group.
- For example, if you have purchased x tickets and the other participants has bought y tickets, the probability that you will win the prize is $\frac{x}{x+y}$.
- In case no tickets are purchased, no one wins the price.

Treatment 2 (Fixed Price Rationing)

- In each round, you and the other participant will play a two-person lottery. The lottery prize is 1600 points. You and the other participant will be given the chance to purchase lottery tickets at 1 point per ticket. As you purchase tickets, your point endowment will be reduced by the value of the tickets purchased.
- There is a total number of 1200 tickets available.

- At the end of each round the computer selects randomly the winning ticket among the 1200 tickets. The owner of the winning ticket wins the prize.
- In case no tickets are purchased, or the winning ticket is not purchased, no one wins the price.
- Note that here are two possible cases:
  1. If the total number of tickets demanded by your group is not greater than 1200, you will receive the number of tickets you demanded. In this case, it is possible that no one bought the winning tickets, in which case no one wins the price.
     Example: if you have purchased 800 tickets and the other participant has purchased 200 tickets, the probability that you will win the prize is $\frac{800}{1200} = \frac{2}{3}$.
  2. If the total number of tickets demanded by your group exceeds 1200, each participant receives a share of the 1200 tickets equal to the number of tickets she purchased divided by the total number of tickets purchased. In this case the number of points you will spend will be equal to the number of tickets you actually received.
     Example: if you have demanded 800 tickets and the other participant has demanded 800 tickets, you will receive $\frac{800}{1600} * 1200 = 600$ tickets, at a cost of 600 points, and the probability that you will win the prize is $\frac{600}{1200} = \frac{1}{2}$.

Treatment 3 (Variable Price Rationing)

- In each round, you and the other participant will play a two-person lottery. The lottery prize is 1600 points. You and the other participant will be given the chance to purchase lottery tickets at 1 point per ticket. As you purchase tickets, your point endowment will be reduced by the value of the tickets purchased.
- There is a total number of 1200 tickets available.
- At the end of each round the computer selects randomly the winning ticket among the 1200 tickets. The owner of the winning ticket wins the prize.
- In case no tickets are purchased, or the winning ticket is not purchased, no one wins the price.
- Note that here are two possible cases:
  1. If the total number of tickets demanded by your group is not greater than 1200, you will receive the number of tickets you demanded. In this case, it is possible that no one bought the winning tickets, in which case no one wins the price.
     Example: if you have purchased 800 tickets and the other participant has purchased 200 tickets, the probability that you will win the prize is $\frac{800}{1200} = \frac{2}{3}$.
  2. If the total number of tickets demanded by your group exceeds 1200, each participant receives a share of the 1200 tickets equal to the number of tickets she purchased divided by the total number of tickets purchased. In this case the number of points you will spend will be equal to the number of tickets you demanded.
     Example: if you have demanded 800 tickets and the other participant has demanded 800 tickets, you will receive $\frac{800}{1600} * 1200 = 600$ tickets, at a cost of 800 points, and the probability that you will win the prize is $\frac{600}{1200} = \frac{1}{2}$.

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