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Interest Group Incentives for Post-lottery Trade Restrictions

By

Adrienne M. Ohler, Hayley H. Chouinard,
and Jonathan K. Yoder

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Adrienne M. Ohler[a], Hayley H. Chouinard[b], Jonathan K. Yoder[c]

[a]*Illinois State University, aohler@ilstu.edu*
[b]*Washington State University, chouinard@wsu.edu*
[c]*Washington State University, yoder@wsu.edu*

Abstract

The rights to use publicly-managed natural resources are sometimes distributed by lottery, and typically these rights are non-transferable. Prohibition of post-lottery permit transfers discourages applicants from entering the lottery solely for profitable permit sale, so only those who personally value the use of the resource apply. However, because permits are distributed randomly and trade is restricted, permits may not be used by those who value them most. We examine a possible rationale for restrictions on permit transfers based on the distribution of welfare across interest groups, and characterize the economic conditions under which post-lottery prohibitions on trade are likely to arise. We develop our model using the specific case of the Four Rivers Lottery used to allocate rafting permits on four river sections in Idaho and Oregon.
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1. Introduction

Lotteries are used to allocate rights to use, access, or consume a variety of publicly managed natural resources. Hunting permits for elk in Montana, moose in Maine, waterfowl in Maryland, and wild turkey in Minnesota are distributed by lottery. Ohio randomly draws winners for the right to fish trout from Cold Creek; and rafting permits for the Yampa River in Colorado are also distributed through a lottery.

Common among these lotteries is a restriction on the transfer of the lottery-allocated rights to other parties. In these cases, only the initial winner of a lottery permit is allowed to actually execute the associated right. The permit cannot be transferred or traded for use by someone else, and this restriction is generally monitored and enforced.

The prohibition on trade of lottery-allocated rights comes at a cost. When rights are distributed randomly and must be used by the winner, the resource may not end up in the hands of those who value it most. The result is that the aggregate rents accrued from the use of the resource are not as high as they would be if trade were allowed (Boyce, 1994; Oi, 1967). Loomis (1980, 1982) examines distribution methods for private rafting permits for the Colorado River. He estimates that rafters face a 43% reduction in welfare when using a lottery with transfer restrictions relative to a pricing system.

If welfare losses from restrictions on right transfers are substantial for resource users, then why are post-lottery transfer restrictions so common? To respond to this question, we consider the primary resource users as an important interest group who potentially has substantial influence on natural resource policy design, and we focus on the objectives of this group and how they might shape the design of natural resource related lotteries. We develop this discussion around Idaho's Four Rivers Lottery, which is a mechanism for distributing permits for private whitewater rafting on four wilderness river sections in Idaho.

A large literature exists that elucidates the economic relationships between regulators and regulated interest groups. In his seminal paper, Stigler (1971) observes that regulated groups themselves are often the beneficiaries of regulation, and as such strive to influence regulatory design. Peltzman (1976) extends Stigler's argument, focusing on the importance of the distributive effects of regulation. One of the primary implications of this work is that interest groups with concentrated benefits from regulation tend to invest more resources into affecting regulation, whereas groups with diffuse benefits (even very large groups), tend to invest less and therefore tend to be less effective at affecting regulatory change in their favor.

We provide a public choice perspective on the reasons for the current lottery structure based on interest group influence, and the conditions under which implementing transfer restrictions makes economic sense from the perspective of the primary user group. We further illustrate that the root of the rent distribution problem for transferable permits is an inability to identify the members of the primary interest group. We provide examples in which the problem of member identification is more easily overcome and transfer restrictions are not imposed. This is the first effort to our knowledge that develops a model to characterize the tradeoff faced by a primary user group between the loss of welfare from prohibiting trade versus the loss of resource rents to non-users from allowing post-lottery trade.

Boyce (1994) provides an extensive analysis of lottery structure, which we use as a foundation for our analysis. Boyce examines the welfare costs of restricting permit trade as we do. However, his model is restricted to the case where the number of applicants is no greater than the number of people who positively value the resource, which disallows exactly the type of rent seeking and rent distribution effects that we examine here. If post-lottery trade is allowed, the (endogenous) number of applicants can be larger than the number of individuals that personally value the resource, and some of the rents may be extracted from the primary user group. Chouinard and Yoder (2004) discusses some of the tradeoffs inherent in post-lottery trade restrictions in the context of rafting permit lotteries, but their analysis is more limited in scope and does not develop an underlying formal modeling framework.

The idea that groups with highly concentrated benefits often disproportionately influence policy design may lie at the heart of why post-lottery prohibitions on trade are common. We examine the tradeoffs faced by users from restricting trade and consider the outcomes with various types of trade. In section 2 we develop a model and apply it to three lottery structures: one with no trade allowed, an open lottery with tradable permits and a lottery where those who don't value the resource are excluded and trade is allowed.[1] In section 3, we compare the welfare implications of these policy options. We illustrate our argument that the fundamental underlying information barrier to the political/economic viability of post-lottery permit trade in section 4. Section 5 concludes.

2. The value of a lottery application

The value of the right to submit a lottery application depends on the value of the permit that might be won, which in turn is a function of the rules governing the use of the permit and the lottery itself. It is useful to categorize potential lottery applicants into two overlapping dichotomous pairings. The first pair of categories is *users* and *nonusers*. The second pair of categories is *sellers* and *buyers*. These shorthand terms are defined as subsets of lottery

[1] For our purposes, the terms "transfer" and "trade" are synonyms.

participants under nontradable and tradable permits as follows:

Users: Individuals who positively value personal use of the resource (willingness to pay (WTP) > 0).

Nonusers: Individuals who receive no value from personal use of the resource (WTP $= 0$).

Buyers: People who would buy a tradable permit at an equilibrium market price if they had not won a permit in the initial lottery.

Sellers: People who would sell their permit at the market price if they were to win a permit.

Based on these definitions, sellers is a group potentially comprised of users and nonusers. User/sellers have positive but relatively low willingness to pay (WTP) for a permit. Nonuser/sellers place no practical value on using a permit, and would not apply to a lottery except to sell the permit for a profit if trading were allowed. The distinction between user/seller and nonuser/seller becomes important in our discussion of welfare distribution across interest groups and its relation to lottery design. Buyers are always users, and nonusers who enter the lottery are always sellers.[2] We consistently and specifically use these definitions anytime we refer to users, nonusers, sellers or buyers.

The distribution of consumers across these groups is central to our hypotheses about observed lottery design. The aggregate demand for the rights to use the resource (net of the non-permit costs) is equivalent to the demand for permits, and is the foundation for the entire analysis that follows.

2.1. The value of a permit

We use specifics of the Four Rivers Lottery for whitewater rafting permits to focus and illustrate our model and results. The U.S. Forest Service (USFS) uses this lottery to distribute rafting permits for portions of the Selway River, Snake River, Main Fork of the Salmon River, and Middle Fork of the Salmon ("Middle Fork") during the summer (Martin,

[2]Despite this bit of redundancy, we will use the full terms user/buyer and nonuser/seller for clarity and consistency.

1987; Michalson, 1977). The USFS ostensibly limits use to reduce congestion on limited camping beaches and the river corridor in general, and to reduce pressure on wildlife habitat and other management objectives (USFS, 2008b).

Rafting permits won in the lottery are nontransferrable. Permit winners from the Four Rivers Lottery do not have the right to sell their permits, and USFS park rangers verify that the permit winner accompanies each rafting group at river launch sites USFS (2008b). If permit transfer were allowed, a secondary market for these permits would likely exist because the market value of these permits would be quite high. Almost ten thousand people applied for a noncommercial permit to float the Middle Fork in 2010, and under four percent of applicants won permits USFS (2008a). Four commercial launches are allowed per day, and commercial guide companies charge between $1,500 and $2,000 per person for a six-day raft trip. This fee covers food and services provided by commercial outfits, but undoubtedly embodies substantial scarcity rents as well.

An individual can submit one application to the lottery per river per year during the application period (usually December through January) for the upcoming summer rafting season. The application form requires the applicant to rank the top four preferred river and date combinations. The USFS awards permits from the pool of applicants on a day-by-day basis. For any given river/day, a name is drawn from the pool of names for which that river/day was listed as their first choice. Only if there are more permits than first choices submitted for a given river/day will the drawing move to that pool of applicants who listed that day as a second choice. There are fewer permits than applicants in the first-choice pool for almost all river/days, so the second-choice pool is of almost no practical relevance. We therefore assume that each applicant applies for one river/day per year.

Private (noncommercial) lottery applicants pay a $6 non-refundable application fee, and permit winners (and their groups) pay $4 per boater for launching (USFS, 2007). Scrogin (2009) compares the welfare results from lotteries with nontradable permits and two types of payment schemes, an “all pay” format in which all applicants pay an application fee to enter the lottery, and a “user pay” format, in which only winners pay. In light of the Four Rivers Lottery fee structure, we examine the case in which application fees and permit fees for winners are both imposed, and examine the welfare implications of adjusting these two instruments for both transferable and non-transferable lottery regimes.

Consider the demand for a permit for one river-date combination.[3] Since each individual can only enter the lottery once, the demand for permits on that river and date is based on each individual's value for one rafting trip net trip costs (Boyce, 1994; Scrogin et al., 2000). Aggregate demand for a given river/day is the value of permits ranked from the individual with the highest WTP to the individual with the lowest WTP. We assume this aggregate demand for permits has the following linear structure:

$$v(q) = \alpha - \beta q - \gamma \bar{q} + \frac{\eta}{\bar{q}} M, \tag{1}$$

where

$$M = s \cdot G,$$

$$G = f_a \cdot q_a + f_p \cdot \bar{q}.$$

The variable q is the rank of an individual in terms of WTP ($q = 1 \Rightarrow$ highest WTP), $\bar{q} \geq 0$ is the number of permits to be awarded, M is river maintenance expenditures, s is the share of lottery revenue spent on river maintenance, G is total lottery revenue, q_a is the number of applicants, f_a is the application fee, and f_p is the permit fee. The parameter β represents the marginal difference in WTP between ranked individuals, and accounts for differences in preferences, travel costs, and budget constraints across individuals. Although rafters differ in their WTP, we assume that all individuals equally dislike congestion, and equally value maintenance. The parameters α, β, γ, and η are non-negative.

As the number of permits increases, the number of boats and people increases. The term $\gamma \bar{q}$ accounts for congestion on the river. We assume congestion negatively affects a person's value of rafting because more rafters cause crowding of the launch site, river, and campsites, so $\gamma > 0$.

We assume river maintenance, M, increases a user's value for rafting, and may increase the pool of users.[4] Maintenance depends on the share of government revenue spent on

[3]River days are substitutes for each other and therefore characteristics and permit availability for one river day of affect demand for permits on other river days. We abstract from this complication by focusing on only one river day. The availability of substitutes nonetheless is implicit in the demand structure.

[4]Boyce (1994) assumes that the fees collected from a lottery are rebated to the population. To be

improvements, $s \cdot G$, where the share is set to at least keep a balanced budget, $0 \leq s \leq 1$. Lottery revenue G is comprised of application fees, f_a, collected from all applicants, q_a, and permit fees, f_p, paid only by permit winners, $\bar{q}$. Maintenance can come in the form of non-rivalrous services (e.g. up-to-date river condition information or road maintenance to river access points), or rivalrous services such as personal attention by managment personnel at the launch site. The term $\frac{\eta}{\bar{q}}$ is the marginal value of maintenance to an individual. The denominator allows for rivalry in maintenance benefits, but the magnitude of the numerator can be interpreted to reflect non-rivalrous benefits of maintenance.

Resource users place a positive value on the resource, and are therefore defined as $q > q_0$, where q_0 is that user who is just indifferent to rafting:

$$\begin{aligned} q_0 &= \{q | v(q_a(f_a, f_p, \bar{q}, s)) = 0\} \\ &= \frac{1}{\beta}\left(\alpha - \gamma\bar{q} + \frac{\eta s}{\bar{q}}\left(f_a q_a + f_p \bar{q}\right)\right). \end{aligned}$$

All else constant, maintenance expenditures increase with the number of applicants, so the number of users increases as the number of applicants increase ($\partial q_0 / \partial q_a = (\eta s f_a)/(\beta \bar{q}) > 0$). This is important as the endogenous nature of the number of applicants and maintenance expenditures causes the number of users to vary between lottery types.

Below we derive user surplus for three cases: a lottery with a permit transfer prohibition, an open lottery where permit transfer is allowed, and a lottery for transferable permits that excludes nonusers.

2.2. Lottery for nontradable permits

In a lottery setting, winners and losers are unknown *ex ante*. We therefore examine the expected surplus rather than post-lottery actual surplus.[5] No nonusers apply for nontradable permits, and expected user surplus for nontradable permits is the sum over permit winners

consistent with our example of the Four Rivers Lottery and most other natural resource lotteries, we assume that fees are only rebated back to the resource users in the form of resource maintenance.

[5]This subsection provides results analogous to results presented in Boyce (1994) and Scrogin et al. (2000).

and applicants who don't win a permit:

$$\begin{aligned} E[S^n] &= [\text{winner surplus}] + [\text{loser surplus}] \\ &= [E[v(q)|q_a^n] - (f_p + f_a)\bar{q}] - [f_a(q_a^n - \bar{q})] \\ &= \int_0^{q_a^n} \frac{\bar{q}}{q_a^n} v(q) dq - \bar{q}\left(f_p + f_a \frac{q_a^n}{\bar{q}}\right), \end{aligned} \tag{2}$$

where q_a^n is the equilibrium number of applicants given tradable permits, $\bar{q}/q_a^n$ is the probability of winning a permit, and $\bar{q}\left(f_p + f_a \frac{q_a^n}{\bar{q}}\right) = \bar{q} f_p + q_a^n f_a$ are total fee expenditures.

To find the equilibrium number of applicants, consider an individual's decision to apply to the lottery. An individual will apply if her expected benefit is greater than her expected cost of applying. The expected benefit from applying is the probability of winning times her personal willingness to pay for a permit, $\frac{\bar{q}}{q_a^n} v(q)$, where the probability of winning is the number of permits divided by the number of applicants. The individual's expected cost of applying is the sum of the application fee and the probability-weighted cost of a permit paid by winners only: $f_a + \frac{\bar{q}}{q_a^n} f_p$. Each applicant can enter the lottery only once, so the rank of the marginal applicant equals the number of applicants for the restricted lottery, q_a^n. For the marginal applicant, the expected net benefit of applying equals zero:

$$v(q_a^n) = f_p + \frac{q_a^n}{\bar{q}} f_a, \tag{3}$$

which implies that the value of a permit to the marginal applicant just equals the revenues received by the agency per available permit. Substituting the right hand side of Equation 1 for $v(q)$ and solving provides the number of applicants for the restricted lottery:

$$q_a^n = \frac{\bar{q}(\alpha - \gamma\bar{q} - f_p\psi)}{\beta\bar{q} + f_a\psi}, \tag{4}$$

where $\psi = 1 - \eta \cdot s \geq 0$.[6] We focus on the case of a binding permit quota such that $q_a^n > \bar{q}$, where the equilibrium number of applicants is greater than the number of permits.

[6]The assumption that $\psi = \eta \cdot s \leq 1$ is not strictly necessary, but it eases interpretation and could be justified as follows: The total contribution to $v(q)$ associated with G through maintenance can be written as $\eta s \frac{G}{\bar{q}}$, where $\frac{G}{\bar{q}}$ is government expenditures per permit holder. If these dollars were given directly back to permit holders instead of used for maintenance, the willingness to pay for this reimbursement would be exactly $1 \cdot \frac{G}{\bar{q}}$. The assumption $\psi = \eta \cdot s \leq 1$ implies that a dollar spent on maintenance provides no more than a dollar's worth of benefit to a permit holder.

It is shown in the Appendix section Appendix A.1.1 that the number of applicants for the restricted lottery, q_a^n, is a subset of the number of users, q_0^n, such that $q_a^n < q_0^n$. No nonusers apply for this lottery because the buying and selling of permits is prohibited, and potential users who value the resource but do not apply due to the fee structure, receive no rents from the resource. The expected surplus for users for a lottery over nontradable permits is

$$\begin{aligned} E[S^n] &= \frac{\beta\bar{q}^2(\alpha - \gamma\bar{q} - f_p\psi)}{2(\beta\bar{q} + f_a\psi)} \\ &= \frac{\beta\bar{q}}{2}q_a^n. \end{aligned} \tag{5}$$

The first line is derived by substituting the right hand side of $v(q)$ from Equation 1 into Equation 2, and the second line by substituting q_a^n from Equation 4.

[Figure 1 about here.]

Figure 1 illustrates surplus for the three types of lotteries we examine. Subfigure 1a illustrates user surplus for the nontradable lottery as area **A**, which is the difference between average expected benefits and expected costs for each permit.[7]

This expected surplus can also be broken down into two groups that become important in terms of surplus distribution in relation to lotteries with tradable permits examined in the next subsection: (a) those users who *would buy* a permit if trade were allowed and they did not win, and (b) those users who *would sell* if trade were allowed and they won a permit. As discussed below, these two groups are determined by the number of permits, $\bar{q}$:

$$\begin{aligned} E[S^n] &= E[S^n|buy] + E[S^n|sell] \\ &= \left[\int_0^{\bar{q}} \frac{\bar{q}}{q_a^n}(v(q) - f_p) - f_a dq\right] + \left[\int_{\bar{q}}^{q_a^n} \frac{q_a^n - \bar{q}}{q_a^n}(v(q) - f_p) - f_a dq\right]. \end{aligned} \tag{6}$$

For a given number of permits and applicants, potential buyers expect to receive more surplus per person than potential sellers because their personal valuation of the resource, and therefore the value of a winning application, is higher.

[7] Boyce (1994) derives and illustrates the same surplus measure, but in a different form. Our representation provides easier comparison for the types of lottery structures we examine here.

2.3. Nonexclusive lottery for tradable permits

We now consider a lottery open to anyone for permits that are tradable after initial lottery allocation. Assume zero transaction and information costs (in both the lottery and in the post-lottery market), and that anyone willing to buy a permit also participates in the lottery and would have paid the application fee for a chance to win. For accounting purposes, assume that a lottery winner pays the permit fee to acquire the right to use or sell the permit. Therefore, a buyer pays the equilibrium permit price and the application fee, but does not pay the permit fee directly to the permit winner.

There is one equilibrium market price for permits, $\bar{v} = v(\bar{q})$, which is equal to the WTP of the $\bar{q}^{th}$ individual. There are $\bar{q}$ potential buyers willing to bid up to this price for a permit, and any winner with a valuation below this price will be better off selling. The expected surplus is

$$E[S^t] = \int_0^{\bar{q}} (v(q) - f_p)dq - f_a q_a^t, \tag{7}$$

where q_a^t is the number of applicants given tradable permits.[8]

With trade, the worst a winner can do is sell for price $v(\bar{q})$, and the marginal applicant breaks even in expected value terms: $\frac{\bar{q}}{q_a^t} \cdot v(\bar{q}) = f_a + \frac{\bar{q}}{q_a^t} f_p$. This can be written as

$$v(\bar{q}) = \frac{q_a^t}{\bar{q}} f_a + f_p, \tag{8}$$

which means that the equilibrium market price equals the per-permit fee revenues in equilibrium, so total revenues equal the area $\bar{v} \cdot \bar{q}$. Substituting parameters from Equation 1 and rearranging provides

$$q_a^t = \frac{\bar{q}\,(\alpha - \beta\bar{q} - \gamma\bar{q} - f_p\psi)}{f_a\psi}. \tag{9}$$

The number of applicants for tradable permits q_a^t is always larger than q_a^n, the number of applicants given no trade (See Appendix section Appendix A.1.2). Further, for reasonable specifications, $q_a^t > q_0^t$, where q_0^t is the number of users given tradable permits. That is to say, there are more applicants than people who value personal use of the resource given

[8]Although initial lottery allocation is random, the aggregate post-trade surplus is actually known with certainty when trade is allowed. However, we maintain the "expected surplus" terminology for consistency across lottery regimes.

equilibrium maintenance expenditures (see Appendix section Appendix A.1.3). This implies some nonusers apply to the lottery.[9]

Substituting Equation 9 into Equation 7, integrating, and simplifying shows that total user surplus simplifies to

$$E[S^t] = \frac{\beta\bar{q}}{2}\bar{q}, \text{ for } \bar{q} \leq q_0^t. \tag{10}$$

This area is illustrated as area **B** in Figure 1b.[10] The zero profit condition for sellers implies that all of the expected net profits due to the difference in permit price and application fees is zero. See Appendix section Appendix A.2.1 for a more detailed breakdown of surplus.

2.4. Exclusive lottery for tradable permits

We now consider the case in which a mechanism is assumed to exists that allows easy exclusion of nonusers from lottery eligibility. To implement this exclusion, suppose that only users, who in equilibrium place a positive value on the resource are eligible. Total welfare accruing to users is $\int_0^{\bar{q}} v(q) - f_p\, dq - f_a q_a^e$, which can be written as

$$\int_0^{\bar{q}} v(q)\, dq - \bar{q}\left(f_p + \frac{q_a^e}{\bar{q}} f_a\right). \tag{11}$$

The applicant pool, q_a^e, is defined to be equal to the user pool, q_0^e. Solving Equation 1 for $v(q_0) = 0$ with the equality $q_a^e = q_0^e$ imposed provides

$$q_a^e = \frac{\bar{q}(\alpha - \bar{q}\gamma + f_p s\eta)}{\bar{q}\beta - f_a s\eta} = q_0^e. \tag{12}$$

Although the number of users changes with the number applicants because of the maintenance feedback, this particular definition of users will be useful for later comparisons.

Substituting equation 12 into equation 11 provides a surplus measure for the exclusive lottery with tradable permits. We show in Appendix section Appendix A.2.2 that this surplus can be written as

$$E[S^e] = 2E[S^n] + E[S^t] - f_a\psi\left(q_a^e - q_a^n\right). \tag{13}$$

[9]The number of users given no trade, q_0^n, is generally less than the number of users given trade, q_0^t, because the increased number of applications when trade is allowed increases the expenditures on maintenance, which in turn increases the number of users, q_0.

[10]For $\bar{q} \geq q_0^t$, the lottery is non-binding, and total surplus would thereafter be $(\beta/2)\bar{q}q_0^t$.

Figure 1c illustrates the surplus for excludable/tradable lottery as area (**B+C**).[11]

3. Comparisons across lottery types

The application fee, permit fee, number of permits, and share of revenue spent on quality improvements are exogenous policy instruments set prior to the lottery. In this section, we examine how surplus received by interest groups is affected by changes in the policy instruments under tradable and nontradable permit regimes. There are three groups of particular interest: users as a whole, potential buyers ($q \leq \bar{q}$), who are the subset of users who place the highest value on the resource, and potential sellers ($\bar{q} < q \leq q_a$). The two subgroups differ in the expected surplus across lottery types, and therefore may have different preferences for lottery structure. We examine differences in the outcomes of the lottery types including the number of applicants, the number of users, the win rates and welfare implications.

Although a limited set of unambiguous results follow from the model presented in the previous section, a more complete set of implications can be examined with simulations. To do so, we utilize the base-case parameters given in Table 1, and alter policy parameters for examination:

[Table 1 about here.]

This parameterization is designed to approximate some key statistics for the lottery structure applied to the Middle Fork of the Salmon river. The average application success rate for the Middle Fork is usually about 4 percent, though this has a high variance depending on the day of the season (the most popular dates are the weeks around the beginning of July). For our base case the success rate is 4.3 percent. The application fee is $6. The permit fee is $4 per person/per day, so we set the total permit fee paid by the ultimate permit user to be $20.[12] The standard number of permits issued per day on the Middle Fork of the

[11]We show in Appendix section Appendix A.1.4 that $q_a^e > q_a^n$.

[12]Note that the $4 permit fee is paid for each member of the rafting group. We assume that each of them pays their own permit fees, and that every applicant makes their application decision independently of other potential members of their group.

Salmon in 2010 was 4. As mentioned earlier, commercial guides charge up to $2,000 per person for a Middle Fork raft trip. These include services such as meals, logistics, and guide expertise that are provided by private groups themselves. The intercept value of $\alpha = 1000$ is meant to represent an approximate choke price for private willingness to pay. The other parameters are approximations that provide reasonable results consistent with the limited metadata available for specification.

[Table 2 about here.]

Results for the base case are presented in Table 2. We will begin with a discussion of win rates, and follow with a discussion of user surplus.

3.1. Win rates across lottery types

The win rate is the number of permits divided by the number of applicants. As shown in Table 2, there are four to five times the number of applicants for the nonexclusive lottery for tradable permits than for the other two lottery types, and the win rate under this lottery type is smallest accordingly. The table also shows that there are over three times the number of applicants (464) for the nonexclusive lottery than there are users (147). Nonusers represent almost 70% of applicants, and when these applicants win, they keep a substantial surplus in the form of a permit sale price.

The win rate for all the lotteries increases with the number of permits as seen in Figure 2.a. The win rate for the nontradable lottery is always higher than the others. Increasing the application fee or the permit fee in Figures 2.b and 2.c increases the win rate for the non-tradable and tradable lotteries as the number of applications goes down. The nonexclusive tradable permit lottery is everywhere below the nontradable lottery win rates as implied by the general analytical finding that $q_a^n < q_a^t$.

[Figure 2 about here.]

The number of applicants increases in the exclusive lottery for tradable permits because of the increase in willingness to pay due to maintenance, which reduces the win rate. Note that the permit fee, which is currently set at $4/person/day, could increase substantially with relatively limited impact on win rates for nontradable permits.

3.2. User surplus comparisons

Table 2 also provides the base case expected surplus measures for all users and each lottery structure. User surplus is almost 25 times larger for nontradable permits than the nonexclusive tradable permits. The losses due to the trade prohibition for nontradable permits are far outweighed by the losses to users from nonusers applying, winning, and selling permits to user/buyers.

In contrast, the surplus received by users under exclusive tradable permits are about 1.8 times larger than the surplus for nontradable permits. This difference stems from several sources. First and foremost are the gains from trade that allow permits to be used by those that value them most highly (see Figure 1 again for reference). Second, there are fewer applicants for nontradable permits, so the average expected cost per application (including the permit fee) is higher. The number of users is smaller ($q_0^n < q_0^e$) because there are less maintenance funds, and this reduces the aggregate user willingness to pay.

The user surplus from exclusive tradable permits is over 40 times that from nonexclusive tradable permits. The surplus losses due to the acquisition and sale by nonusers dominates any surplus received by users from the much higher application revenues supporting maintenance. Note also that users who would sell their permits ($\bar{q} < q < q_0^e < q_0^t$) receive no surplus under an unrestricted lottery, because nonusers enter until the expected net benefits of applying exactly equal the costs of applying. For the exclusive tradable permits however, sellers are better off because they have a higher probability of winning, and therefore a higher expected return from winning and selling a permit.

Figure 3 provides several other perspectives on these differences in surplus. First consider the effects of application and permit fees, shown in Figures 3a and 3b. In both cases, surplus from exclusive tradable permits is initially higher than surplus from nontradable permits, but at higher fee levels nontradable permits are better. Nonexcludable permits are poor performers throughout.

[Figure 3 about here.]

Figure 3c compares expected surplus for all three lottery regimes for a range of $\bar{q}$. For the most part, surplus is highest for the exclusive tradable permits, intermediate for nontradable permits, and lowest for the nonexclusive tradable permits.[13]

Figure 3d differentiates surplus across potential buyers and sellers for nontradable permits and nonexclusive tradable permits. First note that expected surplus for sellers (users and nonusers), $E[S^t|sell]$ is always zero, because nonusers apply until this is the case. $E[S^t|buy]$ represents the surplus to buyers of nonexclusive tradable permits. This surplus is increasing in $\bar{q}$ at an increasing rate up to q_0^t. For nontradable permits, $E[S^n|buy]$ is the surplus received via nontradable permits by users who *would buy* a permit if they had lost and were allowed to buy. $E[S^n|sell]$ is expected surplus that would be received by users with nontradable permits who *would sell* if they had won and were allowed to sell (see Equation 6 for the mathematical representation of these two groups). Figure 3d therefore shows that would-be sellers, who would expect to gain zero surplus under a nonexclusive tradable permit system, would expect to receive the largest aggregate surplus of all groups for $\bar{q} \leq 8$. Would-be buyers are better off in the aggregate with nontradable permits instead of nonexclusive tradable permits, but the difference is not as stark.

Figure 3e shows these surplus measures per person for the relevant group. $E[S^n/\bar{q}|\text{buy}]$ is the expected surplus per potential buyer (that is, individuals q up to $\bar{q}$), and $E[S^n/q_0^n|\text{sell}]$ represents potential sellers, of whom there are substantially more (in base case simulations, $q_a^n = 94$, whereas $\bar{q} = 4$). In contrast to the aggregate surplus shown in the previous figure, would-be buyers under nontradable permits receive higher per-person surplus than would-be sellers. Potential buyers of tradable permits in a nonexclusive lottery receive an intermediate level of per-person surplus.[14]

Finally, Figure 3f shows the difference in surplus per person received by would-be buyers and by sellers for nontradable versus nonexclusive tradable permits. Specifically, the dashed

[13]One interesting exception is for $\bar{q} = 1$, where $E[S^e]$ is less than $E[S^n]$, and even negative. Recall Equation 13, which shows that $E[S^e]$ is equal to the sum of the expected surplus of the tradable lottery and twice the expected surplus from the nontradable permit lottery, minus a multiple of the difference between q_a^e and q_a^n. Figure 3c shows that this difference is largest for low $\bar{q}$. Under our specification, the effect outweighs $E[S^t]$, leading to the reversal in $E[S^e]$ and $E[S^n]$.

[14]Although not shown, both sellers and buyers gain higher per-person surpluses with exclusive tradable permits than their counterparts in the other lottery types.

line labeled "Potential sellers" represents $E[S^n/q_0^n|\bar{q} < q \leq q_0^n] - E[S^t/q_0^t|\bar{q} < q \leq q_0^t]$, and the solid line labeled "Potential buyers" is $E[S^n/q_0^n|q \leq \bar{q}] - E[S^t/q_0^t|q \leq \bar{q}]$. This figure shows that both potential buyers and potential sellers do better with nontradable permits, but sellers will gain more over what they expect to receive for nonexclusive tradable permits, which is zero on average.

In summary, users who place a relatively lower (but positive) value on personal use of the resource likely stand to gain the most, per person and in the aggregate, from maintaining a nontradable permit system instead of a nonexclusive lottery. They have a strong incentive to lobby for and maintain such a system. Further, for all but $\bar{q} = 1$, potential buyers and sellers are both better off in the aggregate under excludable tradable permits compared to nontradable permits (and nonexclusive tradable permits), but again sellers receive the most surplus under an excludable lottery with tradable permits.[15] For sellers in particular, nontradable permits are much better than nonexclusive tradable permits, but exclusive lottery with tradable permits would be better for users if an effective and low cost mechanism for excluding nonusers were available.

4. User identification and tradable permits

Exclusion of nonusers is often difficult. Nonusers have no incentive to disclose the fact that they place no value on personal use, and nonuser self-selection out of a lottery for tradable permits with an unenforced exclusion policy is not likely when rents are to be had from market participation. However, there are circumstances in which users and nonusers can be distinguished via incentive compatible revelation of preferences. Boyce (1994) notes the ability to informally trade moose hunting permits in Maine. More recently, the Moose Permit Swap has become formalized through an internet website and monitored by the Department of Inland Fisheries and Wildlife (DIFW). Swapping of permits can only occur between winners, and the DIFW must be notified of the swap 5 days before the season starts.

[15]The expected surplus for exclusive tradable permits is not illustrated with an additional figure, but it looks essentially the same as the $E[S^n|buy]$ and $E[S^n|sell]$ functions in Figure 3d, but larger in magnitude for both potential buyers and sellers.

In the 2009 season, 3,015 permits were allocated and 334 swaps occurred. Allowing permit trading among winners potentially increases the surplus, because only mutually beneficial trades occur. However, non-hunters are unable to extract rents as effectively, because they cannot sell a permit outright.[16]

From 2000 through 2007, Kansas resident landowners could apply for a transferable permit to hunt whitetail deer (Taylor and Marsh, 2003). In this case, landowners were an interest group that provided wildlife habitat, and therefore had both the capacity to contribute to the welfare and management of wildlife and had a stake in its management (Lueck and Yoder, 1997). Additionally, landowners were an easily identifiable group, and all permit transfers were monitored by the Kansas Department of Wildlife and Parks (KDWP). Implementing a landowner requirement presumably decreased speculation and lottery entry by nonusers and allowed landowners to capture rents from the resale of permits. Interestingly, however, KDWP eliminated the transferable permit system in 2008 stating that it had become "burdensome and confusing to both landowners and hunters."

Up until 2005, wild turkey permits in Maine were allocated through a lottery.footnoteAfter 2005, the number of permits exceeded the number of applicants, making the lottery unnecessary. Hunters could transfer their wild turkey permits to junior hunters or hunters over 65 years old, but the permit holder and transferee must all possess a valid big game hunting license. If turkey hunters are also more likely to participate in big game hunting than people with no interest in turkey hunting, these nonusers would bear a higher net cost of holding a big game license. This additional cost, plus the low value of a turkey permit relative to other large game would likely limit the potential profits from the sale by nonusers of lottery-allocated turkey permits.

[16]Note that in principle an individual could provide or accept a side payment for the difference in the value of two permits being swapped. However, even in this case the value of the least valuable permit would be lost.

5. Conclusion

Lotteries are often implemented to distribute the rights to use publicly held resources, and prohibitions on the trading of these rights are common. We demonstrate that user groups who value personal use of the resource face a welfare tradeoff inherent in restriction. In a system that allows post-lottery permit trade, users with a high willingness to pay may purchase the right to access the resource from a lottery winner in a mutually beneficial transaction, thereby increasing welfare. However, nonusers have an incentive to enter the lottery solely to sell a permit if the benefits of doing so justify the costs. When users buy from nonusers, the surplus from the sale of the permit is lost from the perspective of the user group.

We show that users as a whole prefer the prohibition of post-lottery trade when nonusers are not excludable from the lottery. We also show, interestingly, that low-value users — those who would sell a permit if trade were allowed — stand to gain the most from restricting trade. We also show that users would prefer the ability to transfer rights among themselves if nonusers can be prohibited from entering the lottery. The ability to identify members of the user group becomes vitally important in order to prohibit nonusers from entering the lottery. Mechanisms that can be used to distinguish users from nonusers can increase the surplus of the user interest group, and allow this type of limited transferable lottery to exist. We provide some examples of this type of limited transfer, when even limited but systematic and low cost identification is possible.

Users represent the group who stand to gain the highest concentration of rents from the use of the resource, and so have a relatively strong incentive to exert effort to affect the design of a lottery system. Martin (1987) evaluates several alternative lottery structures for the four river sections now operated under the Four Rivers Lottery. Not surprisingly, the documented discussion and analysis of the Four Rivers Lottery design by policymakers revolves entirely around the resource users. There is basically no recognition that nonusers might have some interest in the design of such lotteries. Public comment opportunities on potential lottery designs were targeted exclusively toward prior permit applicants for the various predecessors of the Four Rivers Lottery (Martin, 1987).

River management agencies clearly pay attention to users in particular. Users are also likely to be motivated to provide input about their preferences. As an example of active interest group activity, American Whitewater (AW) (`http://americanwhitewater.org/`) is a nonprofit organization representing whitewater enthusiasts, including individuals and over 100 local paddling clubs across the U.S. Among other content, AW's website includes news on river access, dam development, hydroelectric dam water release information, water quality, and other issues of interest to boaters. It also includes a "River Stewardship toolkit" that provides guidance for how to effectively contact and influence public representatives. Further, the AW staff writes position papers and provides public testimony, and also organizes river cleanups and other events, among other things. Beyond organized influence, however, the very act of using the resource and interacting directly with managers themselves is likely to lower the costs of conveying preferences and exerting influence on resource management. Thus, individual river users are likely to be in a better position to influence river management than any other group.

In the Four River's Lottery, users would likely prefer an exclusive lottery with tradable permits, but no mechanism currently exists to identify and exclude nonusers from entering the lottery. Policies such as requiring lottery applicants to demonstrate a knowledge of rafting, ownership of rafting equipments, or past rafting experience, may help to identify users, but the effectiveness of such policies is questionable. One potential welfare-enhancing option would be to allow in-kind permit trading among winners only as was previously done for moose hunting permits in Maine, as discussed above. However, the gains from trade in these cases would stem from post-lottery changes in circumstances among winners that lead to different preferences over the timing or river for a rafting trip, and as such, our model does not directly address this situation. Such a system would introduce the possibility for side-payments in trade. Side payments would tend to be lower because giving up the initial permit would in most cases represent an opportunity cost to the initial winner.

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Appendix A.

This appendix provides derivations of several results referred to in the text.

Appendix A.1. Comparisons of Number of Applicants

Appendix A.1.1. The number users for nontradable permits is greater than the number of applicants.

To prove $q_0^n > q_a^n$, note that the marginal applicant for a nontradable permit is $\frac{\bar{q}}{q_a^n} \cdot v(\bar{q}) = f_a + (\bar{q}/q_a^n)f_p$. Substituting $v(\bar{q}) = \alpha - \beta\bar{q} - \gamma\bar{q} + (\eta/\bar{q})M$ and rearranging provides

$$(\alpha - \gamma\bar{q} + (\eta/\bar{q})M) = \beta q_a^n + (q_a^n/\bar{q})f_a + f_p.$$

By definition, WTP=0 at q_0^n: $\alpha - \beta q^0 - \gamma\bar{q} + (\eta/\bar{q})M = 0$, which we can rewrite as

$$(\alpha - \gamma\bar{q} + (\eta/\bar{q})M) = \beta q_n^0.$$

The left-hand side of the two displayed equations above are identical, so substituting βq_0^n from the latter into the former displayed equation and rearranging provides $q_a^n = q_0^n - (1/\beta)((q_a^n/\bar{q})f_a + f_p)$. The term after the minus sign must be positive, implying $q_0^n > q_a^n$.

Appendix A.1.2. The number of applicants for nonexclusive tradable permits is greater than the number of applicants for nontradable permits.

To show that $q_a^t > q_a^n$, as long as there are any applicants at all, rearrange equations 4 and 9, respectively, to get

$$q_a^n(\beta\bar{q} + f_a\psi) = \bar{q}(\alpha - \gamma\bar{q} - f_p\psi)$$
$$q_a^t f_a\psi + \beta\bar{q} = \bar{q}(\alpha - \gamma\bar{q} - f_p\psi).$$

Setting the left sides equal to each other and rearranging provides

$$q_a^t = \frac{(q_a^n - 1)\beta\bar{q}}{f_a\psi} + q_a^n > 0, \qquad \text{for } q_a^n \geq 1.$$

Thus, for practical purposes, there are always more applicants with tradable permits than nontradable.

Appendix A.1.3. The number of users compared to the number of applicants for tradable permits.

For $q_0^t \gtrless q_a^t$, consider the marginal applicant's decision condition $\frac{\bar{q}}{q_a^t} \cdot v(\bar{q}) = f_a + \frac{\bar{q}}{q_a^t} f_p$. Manipulation and provides

$$\frac{\bar{q}}{f_a}\left(\beta(q_0^t - \bar{q}) - f_p\right) = q_a^t.$$

So the relationship between q_0^t and is q_a^t ambiguous. However, For our simulations, q_a^t is larger than q_0^t for reasonable ranges of the policy parameters, as illustrated in Figures 4:

[Figure 4 about here.]

In fact, a comparison with Figures 4a through 4c show that q_a^t is larger than q_0^t for approximately the entire positive surplus space for exclusive tradable lotteries.

Appendix A.1.4. The number of applicants for exclusive tradable permits is greater than the number of applicants for nontradable permits.

Equation 12 representing q_a^e can be rewritten as

$$q_a^e = \frac{[\bar{q}(\alpha - \bar{q}\gamma + f_p\psi] - \bar{q}f_p}{[\beta\bar{q} + f_a\psi] - f_a}.$$

A comparison to q_a^n in equation 4 shows that the contents of the brackets in the numerator and denominator are the numerator and denominator of q_a^n, respectively. Thus, the numerator of q_a^e is bigger than that of q_a^n and the denominator is smaller, implying $q_a^e > q_a^n$.

Appendix A.2. User Surplus

Appendix A.2.1. Surplus for nonexclusive tradable permits

For nonexclusive, tradable permits, total surplus can be broken down into six categories:

$$\begin{aligned} E[S^t] = {} & [\text{winning buyers}] + [\text{losing buyers}] \\ & + [\text{winning user/sellers}] + [\text{losing user/sellers}] \\ & + [\text{winning nonusers}] + [\text{losing nonusers}]. \end{aligned}$$

Letting $\pi = \bar{q}/q_a^t$ equal the probability of winning, and maintaining brackets above,

$$\begin{aligned} E[S^t] = &\left[\pi \int_0^{\bar{q}} v(q) - f_p - f_a dq\right] + \left[(1-\pi) \int_0^{\bar{q}} v(q) - \bar{v} - f_a dq\right] \\ &+ \left[\pi(q_0^t - \bar{q})(\bar{v} - f_p - f_a)\right] + \left[(1-\pi)(q_0^t - \bar{q})(-f_a)\right] \\ &+ \left[\pi(q_a^t - q_0^t)(\bar{v} - f_p - f_a)\right] + \left[(1-\pi)(q_a^t - q_0^t)(-f_a)\right]. \end{aligned}$$

This can also be simplified to

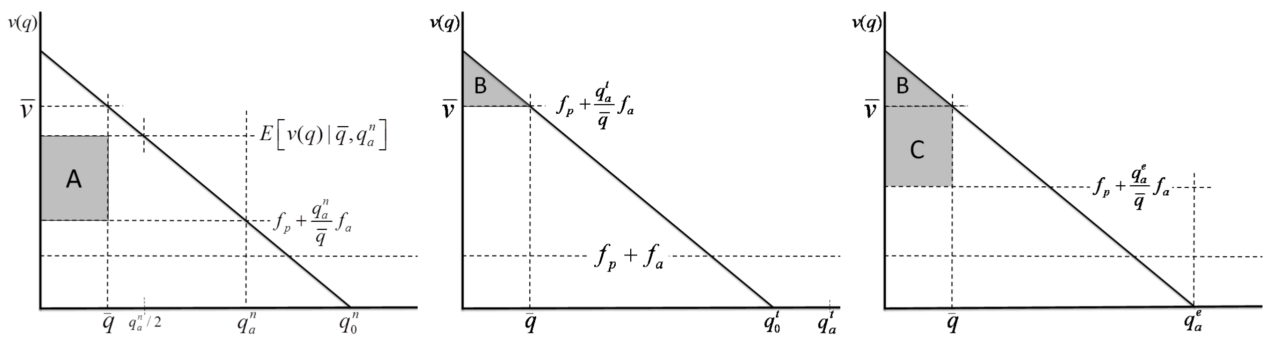
$$\begin{aligned} E[S^t] &= [\text{user buyers}] + [\text{user/sellers}] + [\text{nonusers}] \\ &= \left[\int_0^{\bar{q}} v(q)dq - \bar{q}(\pi f_p + (1-\pi)\bar{v} - f_a)\right] \\ &\quad + \left[(q_0^t - \bar{q})(\pi(\bar{v} - f_p) - f_a)\right] \\ &\quad + \left[(q_a^t - q_0^t)(\pi(\bar{v} - f_p) - f_a)\right]. \end{aligned}$$

Appendix A.2.2. Surplus for exclusive tradable permits

Without substituting the parameterized version of q_a^e, which, after some minor manipulation provides

$$\begin{aligned} E[S^e] &= -(1/2)(\beta + 2\gamma)\bar{q}^2 + \alpha\bar{q} + f_p(s\eta - 1)\bar{q} - f_a q_a^e + f_a q_a^e s\eta) \\ &= (\beta/2)\bar{q}^2 + \bar{q}(\alpha - \gamma\bar{q} - f_p\psi) - f_a q_a^e \psi) \\ &= (\beta/2)\bar{q}^2 + q_a^n \beta\bar{q} + (q_a^n f_a \psi - f_a q_a^e \psi) \\ &= E[S^t] + 2E[S^n] + f_a\psi(q_a^n - q_a^e). \end{aligned}$$

Figure 1: User surplus for nontradable, tradable, and exclusive/tradable permit lotteries.

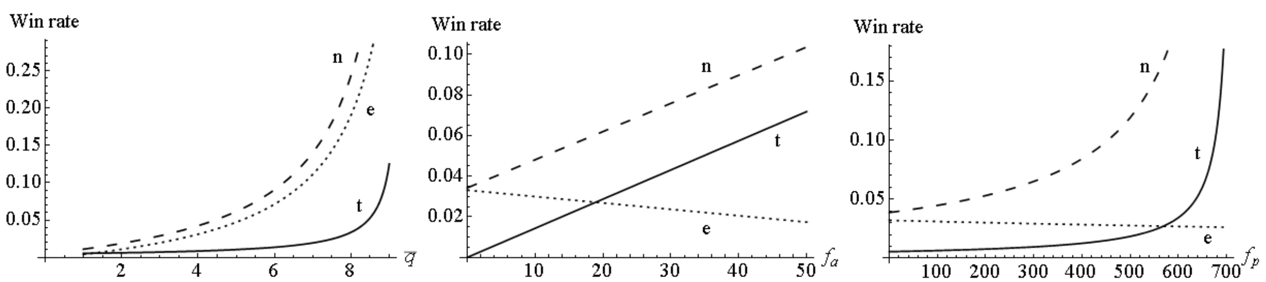


(a) User surplus for nontradable lottery

(b) User surplus for nonexclusive lottery with tradable permits

(c) User surplus for exclusive lottery with tradable permits

Figure 2: Win rates $\bar{q}/q_a$ for nontradable (n), tradable (t), and exclusive tradable (e) permits. Base case parameters shown in Table 2.

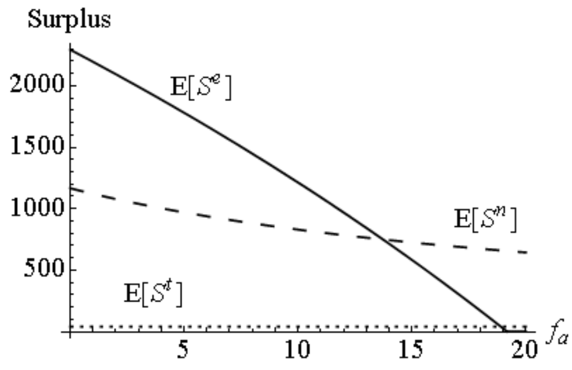


(a) Win rates $\bar{q}/q_a$ as a function of $\bar{q}$.

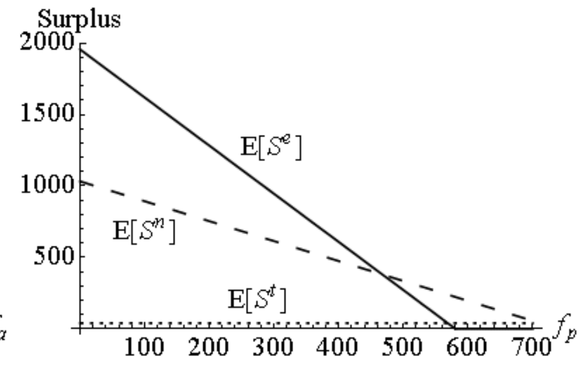
(b) Win rates $\bar{q}/q_a$ as a function of application fees.

(c) Win rates $\bar{q}/q_a$ as a function of permit fees.

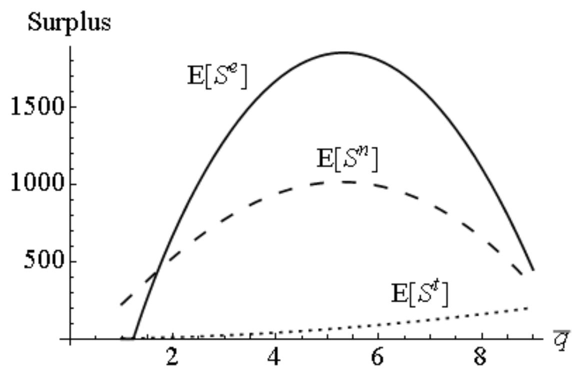
Figure 3: Simulated user surplus for nontradable, tradable, and exclusive/tradable permit lotteries. Base case parameters shown in Table 2.



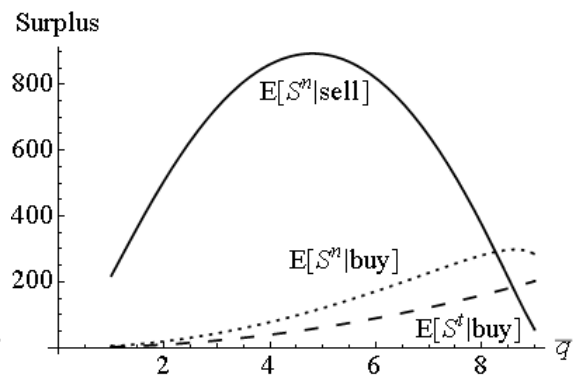
(a) Surplus as a function of application fees.



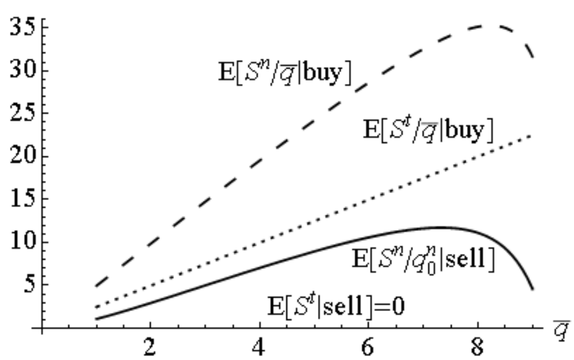
(b) Surplus as a function of permit fees.



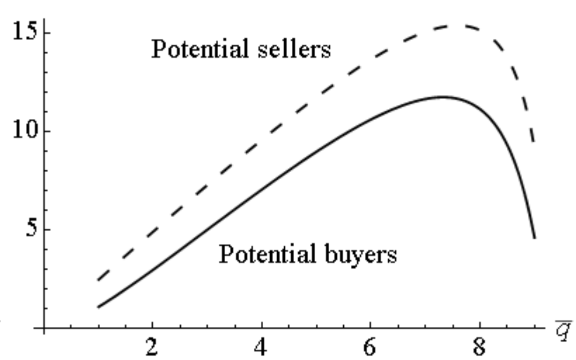
(c) Surplus as a function of $\bar{q}$.



(d) Surplus by user group as a function of $\bar{q}$. For the nontradable lottery, $E[S^n|\text{buy}]$ is the surplus of individuals who would buy if they could. $E[S^n|\text{sell}]$ is the surplus of individuals who would sell if they could.

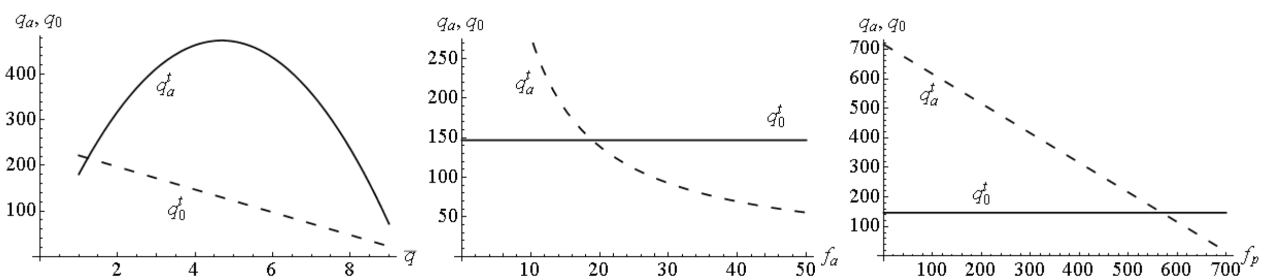


(e) Surplus per user by user group as a function of $\bar{q}$. For the nontradable lottery, $E[S^n/\bar{q}|buy]$ is the surplus of individuals who would buy if they could. $E[S^n/q_0^n|sell]$ is the surplus of individuals who would sell if they could.



(f) Difference in per person surplus received by would-be buyers and sellers for nontradable versus nonexclusive tradable permits, as a function of $\bar{q}$.

Figure 4: q_0^t versus q_a^t as a function of policy parameters.



(a) Applicants q_a and users $\bar{q}_0$ as a function of available permits.

(b) Applicants q_a and users $\bar{q}_0$ as a function of application fees.

(c) Applicants q_a and users $\bar{q}_0$ as a function of permit fees.

Table 1: Simulation parameters.

Parameter	α	β	γ	η	s	$\bar{q}$	f_a	f_p
Value	1000	5	100	0.2	0.95	4	6	20

Table 2: Simulations: base case results for number of applications, number of users, lottery win rates, and total expected user surplus.

Lottery type	q_a	q_0	$\bar{q}/q_a$	$E[S]$
Nontradable (n)	94	126	0.042	939
Nonexclusive tradable (t)	464	147	0.009	40
Exclusive tradable (e)	128	128	0.031	1673