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Private participation in public policy: the economics of strategic lawsuits against public participation

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Private participation in public policy:

The economics of strategic lawsuits against public participation

by

Terrance M. Hurley

A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Department: Economics
Major: Economics

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

For the Major Department

Signature was redacted for privacy.

For the Graduate College

Iowa State University
Ames, Iowa

1995

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ABSTRACT

The primary purpose of this dissertation is to construct a game theoretic model to explore the economic incentives encouraging strategic lawsuits against public participation (SLAPPs), and to explore the efficiency consequences of eliminating SLAPPs. The model that is constructed is a two-stage contest with asymmetric incomplete information regarding agents' benefits. Using the perfect Bayesian equilibrium concept, equilibrium behavior is characterized assuming a ratio contest success function with asymmetric abilities. Comparative static results are derived for the second-stage of the contest, and efficiency is evaluated using contest efficiency as the primitive measure of efficiency where the concept of contest efficiency is developed in an appendix. Given the general ambiguity of the analytic efficiency results, the contest success function is parameterized and efficiency is evaluated assuming that the firm has normal and uniform *a priori* beliefs regarding the distribution of the homeowner's benefit of winning the contest. Finally, the predictive power of the perfect Bayesian equilibrium concept and the intuitive refinement is tested using experimental methods and a specific case of the general SLAPP model. The primary conclusions are that SLAPPs represent a strategic commitment of effort by an agent with incomplete information and relatively low benefits and/or ability to reduce the total amount of effort invested in the contest, and that the elimination of SLAPPs will either reduce or have no effect on the efficiency of the contest.

INTRODUCTION

In the early 1970s, clauses written into the Clean Air and Water Acts granted private

citizens the right to sue firms violating environmental regulations. These clauses were

characteristic of a three decade trend by Congress and the courts to increase private

participation in the enforcement of regulations where government efforts had failed due to a

lack of resources and/or motivation (see Jordan 1987). Since this time, Pring and Canan

(1993) have found evidence of a proliferation of lawsuits that claim "injury from citizen efforts

to influence a government body or electorate on an issue of public significance." Pring and

Canan (1993) find that these multi-million dollar lawsuits, labeled strategic lawsuits against

public participation (SLAPPs), have occurred in conflicts involving environmental protection

and animal rights, as well as real estate development and zoning, neighborhood (NIMBY)

problems, civil rights, consumer issues and criticism of public officials and employees. In the

seventy SLAPPs investigated by Canan and Pring (1988), the average claim for damages by a

plaintiff was $7.4 million, with one plaintiff claiming damages of $100 million. Canan and

Pring (1988) also note that in thirteen particular SLAPPs it took an average of about 31.4

months to resolve the SLAPP with one SLAPP requiring 140 months to dispose with the

defendant emerging victorious. While many of these lawsuits are eventually decided in favor

of the defendant, the anecdotal evidence provided here suggest the cost of SLAPPs, including

legal fees and time, is significant. Based on their analysis, Pring and Canan (1993) conclude

that these strategic, retaliatory lawsuits discourage the continued and future involvement of

private citizens in the political process, and violate these private citizens' first amendment

rights to free speech. They also conclude that reform is necessary, and suggest alternative

judicial, legislative and executive cures as well as reform within the legal profession aimed at discouraging future SLAPPs.

While Pring and Canan formulate their argument against SLAPPs based on an interpretation that SLAPPs are a retaliatory civil rights violation, they do not consider the economic implications of SLAPPs further than recognizing that the cost of the conflict associated with a SLAPP may be significant.[1] Important questions that remain regard the economic incentives and consequences of SLAPPs. For instance, what are the economic incentives encouraging SLAPPs, and what are the efficiency consequences of eliminating SLAPPs? The purpose of this dissertation is to explore these questions within the context of a contest model with asymmetric incomplete information and endogenous timing using the perfect Bayesian equilibrium as the solution concept. The predictive power of the perfect Bayesian equilibrium concept and the intuitive refinement is then tested using a specific case of the SLAPP model and experimental methods.

Strategic Lawsuits Against Public Participation: An Example of a Simple Game

To illustrate the basic structure of the model, consider the simple example of the externality conflict diagrammed in Figure 1. A firm has just purchased a large parcel of land in a residential neighborhood in order to build a shopping mall. A local homeowner or group of homeowners hear of the firm's plan to develop and become fearful that their nice, quiet neighborhood is about to be overwhelmed with congestion, and increased crime due to an

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[1] Canan and Pring(1988) do recognize the possible social cost associated with citizen abuse of the process, but leave this question open for future investigation.
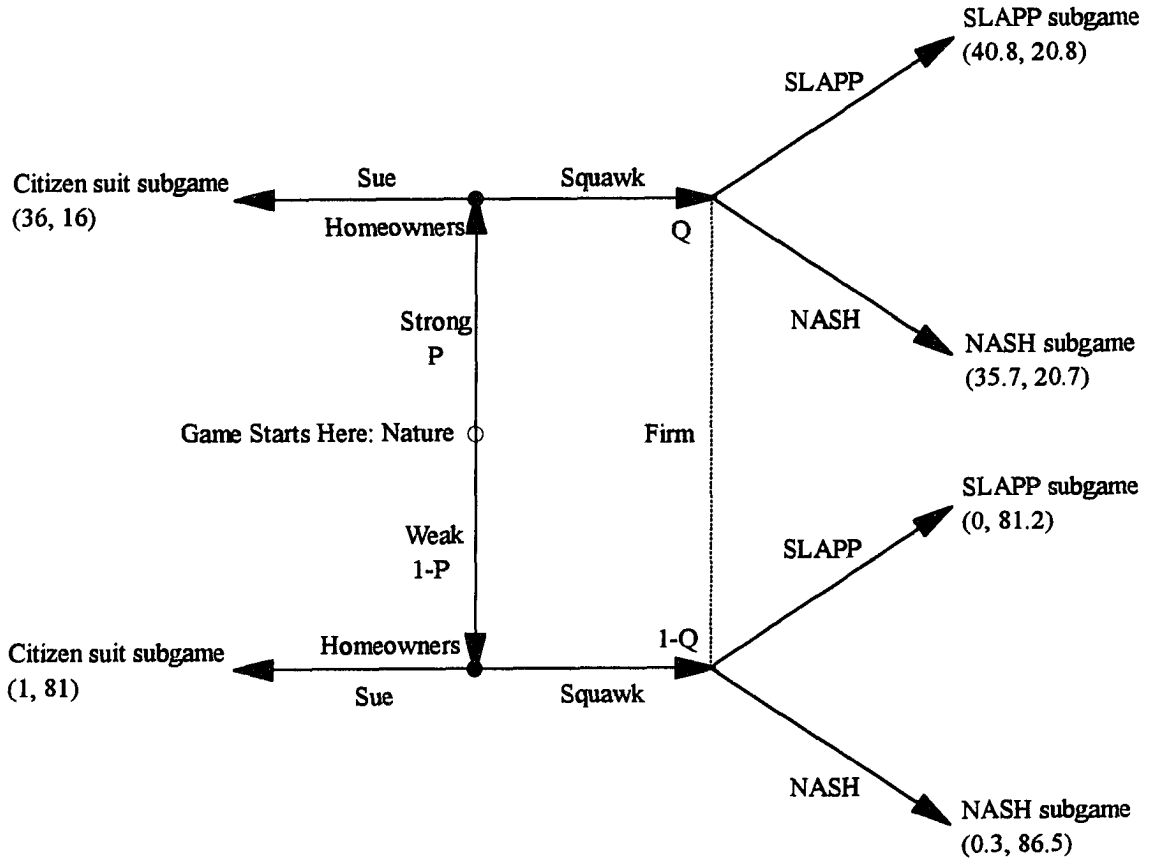
Figure 1: Simplified extensive form SLAPP game

influx of people coming to the mall from surrounding areas. The homeowner has a choice to make. She can idly stand by and watch her quality of life deteriorate, or she can become an active private citizen and contest the firm's decision to build the shopping mall. The homeowner's decision depends crucially on how the homeowner values the development. In some cases, the benefit to the homeowner of having convenient shopping may outweigh the cost of increased congestion and crime, in which case, the homeowner might favor the development. However, if this is not the case, the homeowner will fight the development.

Assume that the homeowner can expend irreversible and observable effort that decreases the probability that the firm develops the land. The firm can also expend irreversible and observable effort to increase the probability that it can proceed with the development. Effort can be thought of as attorneys fees, cost of discovery, court fees and other cost common to political and legal action that increase the probability that the party expending the effort prevails in the conflict.

The homeowner is aware of the firm's potential gain because she has seen the results of similar developments in the past. However, the firm is not sure if the homeowner or homeowners consist of a well organized group of private citizens that have a high negative valuation should the development occur, or a single environmental fanatic who has little support of her neighbors and a low valuation relative to the firm. This assumption is consistent with the observation that the cost of preventing an externality is generally well defined because it involves profits which are observable (at least in theory), while the benefit of preventing the externality is usually not well defined because it involves agents' utilities which are unobservable (both in theory and in practice). Since the firm does not know the

strength of the homeowner's preferences, the firm does not know who, if anybody, will

contest its development. Before the firm can defend its right to develop it must wait for any

homeowner against the development to reveal themselves.

Explicitly, assume the homeowner has either strong or weak preferences against the

development. This is seen in Figure 1 as Nature randomly choosing the strong type of

homeowner with probability P and the weak type with probability 1 - P. P is often interpreted

in the literature as the firm's *a priori* belief that the homeowner has strong preferences. Given

the development is not allowed to occur, assume homeowner with strong preferences avoids a

loss of 120, while the homeowner with weak preferences avoids a loss of 20. Also assume

that the firm receives 100 given the development is allowed to proceed. The homeowner's

avoided loss and the firm's gain are measured in comparable units, for instance, thousands of

dollars.

Consider a two-stage game.[2] In the first-stage, the firm and homeowner determine the

sequence of play in the second-stage. This stage is seen in Figure 1 as the homeowner's

choice of Sue or Squawk given Nature's choice of the homeowner's preferences, and the

firm's choice of SLAPP or NASH given the homeowner chooses Squawk. Sue can be

thought of as a homeowner's private consultation with an attorney which is them immediately

followed by a strategic commitment of effort in the second-stage of the game. Squawk can be

thought of as a costless public display by the homeowner expressing her aversion to the firm's

---

[2] Because a game of incomplete information is being considered, the firm does not know Nature's initial move. Therefore, when the two stages of the game are discussed, the interpretations of a stage and a subgame are slightly different from the formal definitions of a stage and a subgame in Fudenberg and Tirole (1992).

plan to develop. SLAPP can be thought of as a firm's private consultation with an attorney which is then followed by a strategic commitment of effort in the second-stage of the game. NASH can be thought of as a costless public display by the firm expressing its desire to proceed with its development plans which is then immediately followed by a simultaneous commitment of effort by the firm and homeowner in the second-stage of the game.

In the second-stage, the firm and homeowner determine how much effort to invest in a contest that yields 100 to the firm and 0 to the homeowner given the firm prevails, or 0 to the firm and 120 to the strong type homeowner or 20 to the weak type homeowner given the homeowner prevails. The second-stage is not explicitly diagrammed in Figure 1, but the results of the second-stage are captured by the assumed expected payoffs where the first expected payoff in parentheses is the homeowner's and the second expected payoff in parentheses is the firm's. The magnitude of these expected payoffs are indicative of one possible type of outcome for the second-stage of the game in the formal model presented later.

There are three possible sequences of play for the second-stage of the game depending on the actions taken in the first-stage of the game. First, when the homeowner chooses Sue, she strategically commits and reveals her effort to the firm before the firm chooses its effort. In this case, the second-stage of the game is a sequential move contest of complete information which is called the Citizen suit subgame in Figure 1. The expected payoffs to the homeowner and the firm in this case are 36 and 16 given the homeowner's type is strong, and 1 and 81 given the homeowner's type is weak. Second, when the homeowner chooses Squawk and the firm chooses SLAPP, the firm strategically commits and reveals its effort to

the homeowner before the homeowner chooses her effort. In this case, the second-stage

game is a sequential move contest of incomplete information which is called the SLAPP

subgame in Figure 1 because this sequence of play is interpreted as a SLAPP. This sequence

of play is interpreted as a SLAPP because it captures the strategic commitment of effort by

the firm that is characteristic of SLAPPs. The expected payoffs to the homeowner and the

firm in this case are 40.8 and 20.8 given the homeowner's type is strong, and 0 and 81.2 given

the homeowner's type is weak. Third, when the homeowner chooses Squawk and the firm

chooses NASH, the firm and the homeowner choose effort simultaneously with neither agent

knowing the level of effort of the their opponent before they move. In this case, the game is a

simultaneous move contest of incomplete information which is called the NASH subgame in

Figure 1. The expected payoffs to the homeowner and the firm in this case are 35.7 and 20.7

given the homeowner's type is strong, and 0.3 and 86.5 given the homeowner's type is weak.

The first-stage of the game is entered only by a homeowner who is willing to contest

the firm's desire to develop. Which action the homeowner takes in the first-stage of the game

reveals information to the firm. If the homeowner chooses Sue then she essentially reveals her

type to the firm, and the firm can choose its effort knowing the homeowner's type and effort.[3]

If the homeowner chooses Squawk, the firm updates its beliefs regarding the homeowner's

type such that Q in Figure 1 is the probability that the homeowner's type is strong and 1 - Q is

the probability that the homeowner's type is weak.

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[3] In the formal model, it will become apparent that once the homeowner reveals her effort, the firm is able to deduce the homeowner's type from this information.

Two comments are in order. First, the payoffs in the second-stage of the game are assumed to be independent of the firm's beliefs. This does not generalize to the formal model because the homeowner's and firm's optimal efforts depend on the firm's updated beliefs which in turn depend on the firm's *a priori* beliefs. Second, while it may not be clear from the diagram, the effort the firm chooses when it chooses SLAPP is the same regardless of the homeowner's type. This is also true when the firm chooses NASH.

Consider the first question, what are the economic incentives encouraging SLAPPs? There are four possible types of pure strategy equilibria that can exist for this game.[4] There are two types of separating equilibria, one where a weak homeowner chooses Sue and a strong homeowner chooses Squawk, and one where a weak homeowner chooses Squawk and a strong homeowner chooses Sue. There are two types of pooling equilibria, one where both types of homeowners choose Sue, and one where both types choose Squawk.

Given the assumed expected payoffs, the solution to this game is determined by first considering the firm's optimal action given the homeowner chooses Squawk. Given the firm's updated beliefs, the expected payoff to the firm from choosing SLAPP is $20.8Q + 81.2(1-Q)$, while choosing NASH yields $20.7Q + 86.5(1-Q)$ on average. This implies that the firm chooses SLAPP given $Q > 0.98$, or that the firm will choose SLAPP when it has a strong updated belief that the homeowner's type is strong given the homeowner Squawks.

Consider a homeowner's best response given the firm chooses SLAPP. If the homeowner's type is strong, then the homeowner prefers Squawk because $40.8 > 36$. If the

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[4] While only pure strategies are considered to keep this example simple, in a model with only two types, there are actually nine possible types of equilibria including mixed strategies.

homeowner's type is weak, then the homeowner prefers Sue because 1.0 > 0. Given that only

a strong homeowner will choose Squawk, the firm's updated beliefs according to Bayes rule is

Q = 1.0. Since Q = 1.0 is consistent with the firm choosing SLAPP given the homeowner

chooses Squawk, this strategy combination is a perfect Bayesian equilibrium.[5] This strategy

combination leads to a separating equilibrium where a strong type homeowner's action reveals

her type to the firm.

Now consider a homeowner's best response given the firm chooses NASH. In this

case, both strong and weak homeowners choose to Sue because 36 > 35.7 and 1 > 0.3. Since

a homeowner never chooses Squawk, the firm's decision is off the equilibrium path. The firm

is willing to play NASH to support this perfect Bayesian equilibrium provided Q < 0.98.

However, inspecting a weak homeowner's expected payoffs, the worst possible payoff given

a weak homeowner Sues dominates the maximum possible payoff given a weak homeowner

Squawks. This suggest that it is not reasonable for the firm to believe that a homeowner is

weak given Squawk is observed. Conversely, a strong homeowner's worst possible payoff

given she Sues is dominated by her best possible payoff given she Squawks. This suggest that

it is reasonable for a firm to believe that a strong homeowner may choose Squawk. Since it is

never reasonable for a weak homeowner to Squawk, but is reasonable for a strong

homeowner to Squawk, the only reasonable off the equilibrium path belief for the firm is Q =

1.0.[6] Given Q > 0.98, the firm prefers to deviate from NASH to SLAPP. This implies that

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[5] The concept of a perfect Bayesian equilibrium is defined explicitly later, but in essence, behavior must be sequentially rational, beliefs must be updated by Bayes law where possible, and must be consistent with equilibrium behavior when Bayes rule does not apply off the equilibrium path.
[6] See Kreps (1990) for a discussion of dominated messages, pp. 436.

while the combination of strategies above form a perfect Bayesian equilibrium these strategies can not be supported by reasonable beliefs.[7]

Suppose the opportunity for the firm to SLAPP is eliminated as proposed by Pring and Canan (1993). This is interpreted in the game as the elimination of the SLAPP action available to the firm in Figure 1. In this case, the game reduces to the homeowner choosing whether to play the Citizen suit subgame or the NASH subgame. As discussed above, given a choice between the NASH subgame and the Citizen suit subgame, both homeowners' types prefer the Citizen suit subgame and choose Sue. This strategy combination is a pooling equilibrium.

The result that the type of equilibrium depends on whether the firm has the option to SLAPP is an important result that also exists in the formal model and inspires the second question. If eliminating SLAPPs from the firm's list of available options changes the type of equilibrium, is a SLAPP-free equilibrium more or less efficient? In this example, the SLAPP-free equilibrium is less efficient.

In this model, efficiency is defined as the sum of the expected payoffs in equilibrium divided by the maximum of the homeowners' and firm's benefits. This definition is chosen assuming expected payoffs can be freely redistributed. If expected payoffs can be freely redistributed, utility functions are increasing in income and the welfare function is increasing in

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[7] A refinement of the perfect Bayesian equilibrium is resorted to in this case such that the results of the simplified model correspond with the formal model. In the formal model, when payoffs are a function of beliefs, the perfect Bayesian equilibrium concept is strong enough to rule out the possibility that a firm will ever play the NASH action. However, when payoffs in the second stage of the game are a function of the firm's beliefs, as in the formal model, multiple equilibria similar to the multiple equilibria presented here reappear.

individuals' utilities, then social welfare can be maximized by maximizing the expected payoffs and redistributing the income between the homeowner and the firm. If it is possible to settle the conflict out of court with no transaction cost, such as a Coasian solution, the maximum achievable expected benefit to be redistributed is the maximum of the homeowner's and firm's benefits. For example, if the homeowner's type is weak the maximum possible sum of expected payoffs is the firm's benefit, 100, given the firm and the homeowner costlessly agree to let the firm develop. If the homeowner's type is strong the maximum possible sum of expected payoffs is 120. Dividing the sum of expected payoffs by the maximum possible sum of expected payoffs makes relative efficiency comparable across homeowners with weak and strong types.

When a homeowner is strong, the efficiencies of the Citizen suit subgame, the SLAPP subgame and the NASH subgame are 43.3%, 51.3%, and 47%, respectively. When a homeowner is weak the efficiencies of the Citizen suit subgame, the SLAPP subgame and the NASH subgame are 82%, 81.2%, and 86.8%, respectively. In the equilibrium where the SLAPP action is available, the most efficient game is played when the homeowner's type is strong. However, when the homeowner's type is weak, the Citizen suit subgame is played even though the NASH subgame is more efficient. This suggest that the efficiency of the contest may be improved by imposing a policy that maintains the incentives for a strong homeowner and the firm to play the SLAPP subgame while providing an incentive for a weak homeowner and the firm to play the NASH subgame.

The policy suggested by Pring and Canan (1993) is the elimination of the firm's ability to SLAPP the homeowner. While this does change the equilibrium, it does not change the

equilibrium by maintaining the incentives when a homeowner is strong and changing incentives when a homeowner is weak. Instead, it changes the incentives when a homeowner is strong, and does not alter the incentives when a homeowner is weak. This leads to a contest that is less efficient when a homeowner is strong, and has no effect on efficiency when a homeowner is weak.

This example illustrates two important points. First, eliminating SLAPPs can significantly alter the economic incentives of agents involved in a dispute over an externality. Second, eliminating SLAPPs can alter the efficiency of a conflict. In the example presented here, efficiency is unambiguously reduced. These results are echoed throughout formal analysis with the exception that beliefs take an even more prominent role in the formal model.

Strategic Lawsuits Against Public Participation: The Formal Model

The formal model extends the simplified model in two ways. First, a continuum of homeowner's types is considered. Second, the homeowner's and firm's choices of effort are explicitly modeled.

Define V_f to be the firm's benefit from developing the shopping mall measured in thousands of dollars. Let ϖ_h be the proportion of the homeowner's realized benefit relative to the firm's benefit if the firm is not allowed to develop. That is, if V_h is the homeowner's benefit, then $\varpi_h = V_h / V_f$. V_f is common knowledge, while ϖ_h is known only to the homeowner. Also, for future use, define $\varpi_f = V_f / V_h$ which is the firm's benefit relative to the homeowner's benefit.

Define x_i to be the ith agent's observable and irreversible level of effort where i = h for the homeowner and i = f for the firm. Let $\Lambda_i(x_i)$ be the ith agent's cost of effort applying the standard assumptions of non-decreasing marginal cost such that $\Lambda_i'(x_i) > 0$, and $\Lambda_i''(x_i) > 0$ for i = {h, f} where the prime and double prime denote the first and second derivative of the ith agent's cost function with respect to effort. $\Lambda_i(x_i)$ is common knowledge.

$P(x_f, x_h)$ is the probability that the firm is allowed to develop and receives V_f given the firm's and homeowner's levels of effort x_f and x_h. 1 - $P(x_f, x_h)$ is the probability that the firm is not allowed to develop and the homeowner receives V_h given x_f and x_h. From this point on, $P(x_f, x_h)$ is referred to as the contest success function following Hirshleifer (1989). Assuming diminishing marginal returns, $P_{x_f}(x_f, x_h) > 0$, $P_{x_f x_f}(x_f, x_h) < 0$, $P_{x_h}(x_f, x_h) < 0$, $P_{x_h x_h}(x_f, x_h) > 0$ and $0 \leq P(x_f, x_h) \leq 1$ where $P_{x_i}(x_f, x_h)$ and $P_{x_i x_i}(x_f, x_h)$ represent the first and second partial derivatives of the contest success function with respect to the ith agent's level of effort. $P(x_f, x_h)$ is common knowledge.

Since the firm does not know ϖ_h, its information is incomplete. Harsanyi (1967-1968) suggests the introduction of an additional player, Nature, to transform a game of incomplete information into a game of imperfect information. Let v be a random variable from the cumulative distribution $G(v, \tau)$ with density $g(v, \tau)$ such that v is defined over the entire real line. The random variable v represents the homeowner's type defined in terms of the homeowner's benefit relative to the firm. The cumulative distribution $G(v, \tau)$ represents the firm's *a priori* beliefs regarding the probability that the homeowner is type v. $G(v, \tau)$ is common knowledge.

Recall from the simplified model that when the homeowner chooses to Sue or Squawk information is revealed to the firm. The firm uses this information to update its beliefs such that $\Gamma(v,\tau)$ is the cumulative distribution of the firm's updated beliefs. The firm's updated beliefs given Sue are $\Gamma(v,\tau) = 0$ for $v < \varpi_h$ and $\Gamma(v,t) = 1$ otherwise.[8] The firm's updated beliefs given Squawk are more involved and depend on whether the Squawk action is on the equilibrium path. Generally, define the firm's updated beliefs given Squawk as $\Gamma(v,\tau) = \Phi(v,\tau)$. $\Phi(v,\tau)$ is assumed to be common knowledge.

Assuming risk neutrality, a homeowner's expected payoff given her type is

$$E\pi_h(x_f, x_h) = \left(1 - P(x_f, x_h)\right)V_h - \Lambda_h(x_h). \tag{1}$$

The firm's expected payoff given its updated beliefs about the homeowner's type is

$$E\pi_f(x_f, x_h) = \int_{v \in R}\left(P(x_f, x_h(v))V_f - \Lambda_f(x_f)\right)d\Gamma(v,\tau). \tag{2}$$

What information is available when the homeowner and the firm choose their optimal levels of effort depends on the sequence of moves in the first-stage of the game. For instance, if the homeowner chooses Squawk and the firm chooses SLAPP, then the firm must choose its level of effort only knowing $\Phi(v,\tau)$, and the homeowner chooses her level of effort knowing the firm's choice of effort. If the homeowner chooses Squawk and the firm chooses

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[8] When the homeowner chooses Sue, she reveals her level of effort to the firm before the firm chooses its level of effort. It will become clear below that this action essentially reveals the homeowner's type to the firm or the set of types that employ the same equilibrium effort. Technically, the firm only knows the set of types that employ the same equilibrium effort. However, the innocuous assumption that the firm knows the actual type does not alter the firm's choice of effort since all homeowner's types in this set employ the same equilibrium effort, and the firm's equilibrium effort depends only on the homeowner's choice of effort.

NASH, then the firm must choose its level of effort only knowing $\Phi(v, \tau)$, and the homeowner chooses her level of effort only knowing that the firm will choose its level of effort based on $\Phi(v,\tau)$. If the homeowner chooses Sue, she chooses her level of effort and reveals this level of effort to the firm. The firm then chooses its level of effort knowing the homeowner's level of effort.

THE PERFECT BAYESIAN EQUILIBRIUM IN THE SECOND-STAGE SUBGAMES

Before determining the equilibrium for the game as a whole, solutions for the three alternative second-stage subgames must be derived. First, the conditions needed for an equilibrium to exist in the three second-stage subgames are outlined. Second, the general nature of these three second-stage subgame equilibria is discussed. Third, assuming the contest success function is of a commonly used ratio form, analytic solutions are derived along with comparative static results for important model parameters.

General Existence Conditions for an Equilibrium in the Second-Stage Subgames

Proposition 1: A unique, pure strategy, perfect Bayesian equilibrium exists for each of the three second-stage subgames provided second-order conditions for a maximum are satisfied.

The proof proceeds in three steps. The first step establishes the existence of a unique perfect Bayesian equilibrium in the NASH subgame under the present assumptions of the model. The second step establishes the existence of a unique perfect Bayesian equilibrium in the SLAPP subgame provided that the second-order condition for a maximum is satisfied. The third step establishes the existence of a unique perfect Bayesian equilibrium in the Citizen suit subgame provided that the second-order condition for a maximum is satisfied.

Proof: A perfect Bayesian equilibrium extends the concept of subgame perfection to games with incomplete information (see Fudenberg and Tirole 1991, pp. 321-322). Rasmusen (1989, p. 110) defines a perfect Bayesian equilibrium for a general game as "strategy combinations and a set of beliefs μ such that at each node of the game:

(1) The strategies for the remainder of the game are Nash given the beliefs and strategies of other players.

(2) The beliefs at each information set are rational given the evidence appearing that far in the game (meaning that they are based, if possible, on priors updated by Bayes's Rule given the observed actions of the other players under the hypothesis that they are in equilibrium)."

Step 1: In the NASH subgame, the homeowner and the firm choose their effort unaware of their opponent's choice of effort and given the firm's updated beliefs from the first-stage of the game. A strategy for the firm is to choose a level of effort x_f such that $x_f \geq 0$. A strategy for the homeowner is to choose a level of effort x_h such that $x_h \geq 0$. Since no new information is revealed through the play of the NASH subgame, there is no opportunity for the firm to update its beliefs further. This implies that the homeowner's and firm's equilibrium strategies must only satisfy condition (1) for a perfect Bayesian equilibrium.

The firm's objective is $\underset{x_f}{Max} \ E\pi_f(x_f, x_h)$ such that $x_f \geq 0$. The first-order conditions for the firm are

$$\frac{\partial E\pi_f}{\partial x_f} = \int_{v \in R} \left(P_{x_f}(x_f, x_h(v))V_f - \Lambda_f{}'(x_f) \right) d\Phi(v, \tau) \leq 0 \text{ and} \tag{3}$$

$$x_f \frac{\partial E\pi_f}{\partial x_f} = 0. \tag{4}$$

The second-order condition for the firm is

$$\frac{\partial^2 E\pi_f}{\partial x_f^2} = \int_{v \in R} \left(P_{x_f x_f}(x_f, x_h(v))V_f - \Lambda_f{}''(x_f) \right) d\Phi(v, \tau) < 0. \tag{5}$$

Equation (5) is satisfied by assumption. Therefore, the firm's best response, $x_f(x_h)$, that

satisfies equations (3) and (4) for a given $x_h(v)$ exists and is unique.

The homeowners' objective is $\underset{x_h}{Max} \; E\pi_h(x_f, x_h)$ such that $x_h \geq 0$. The first-order

conditions for the homeowner are

$$\frac{\partial E\pi_h}{\partial x_h} = -P_{x_h}(x_f, x_h)V_h - \Lambda_h'(x_h) \leq 0, \text{ and} \qquad (6)$$

$$x_h \frac{\partial E\pi_h}{\partial x_h} = 0. \qquad (7)$$

The second-order condition for the homeowner is

$$\frac{\partial^2 E\pi_h}{\partial x_h^2} = -P_{x_h x_h}(x_f, x_h)V_h - \Lambda_h''(x_h) < 0. \qquad (8)$$

Equation (8) is satisfied by assumption. Therefore, the homeowner's best response, $x_h(x_f, \varpi_h)$

that satisfies equations (6) and (7) for a given x_f and ϖ_h exists and is unique.

Substituting $x_h(x_f, \varpi_h)$ satisfying equations (6) and (7) into equations (3) and (4) yields

the firm's unique equilibrium level of effort for the NASH subgame, x_f^N. Substituting x_f^N and

ϖ_h into Equations (6) and (7) yields the homeowner's unique equilibrium level of effort in the

NASH subgame, x_h^N. By construction, x_f^N and x_h^N satisfy condition (1) above. Therefore,

these unique equilibrium levels of effort form a perfect Bayesian equilibrium for the NASH

subgame.

Step 2: In the SLAPP subgame, the firm chooses its level of effort and reveals its

choice to the homeowner before the homeowner chooses her level of effort. With this

sequence of play, after the homeowner has chosen Squawk, no new information is revealed to

the firm in the SLAPP subgame. Therefore, a perfect Bayesian equilibrium in this subgame

only requires that condition (1) is satisfied. A strategy for the firm is to choose a level of

effort x_f such that $x_f \geq 0$. A strategy for the homeowner is to choose a function $x_h(x_f, \varpi_h)$ such

that $x_h(x_f, \varpi_h) \geq 0$.

In this case, the homeowner's objective is unchanged with the exception that the

homeowner knows the firm's level of effort when she chooses her level of effort. The

homeowner chooses her best response $x_h(x_f, \varpi_h) = \underset{x_h}{Arg \max} \; E\pi_h(x_f, x_h)$ such that equations

(6) and (7) are satisfied given x_f. Since equation (8) is satisfied by assumption $x_h(x_f, \varpi_h)$ exists

and is unique given x_f and ϖ_h.

Since the firm moves first and realizes that the homeowner will respond according to

$x_h(x_f, \varpi_h)$, the firm's objective becomes $\underset{x_f}{Max} \; E\pi_f\left(x_f, x_h(x_f, v)\right)$ such that $x_f \geq 0$. The firm's

first-order conditions suppressing functional arguments to ease exposition are now

$$\frac{\partial E\pi_f}{\partial x_f} = \int_{v \in R} \left(P_{x_f} V_f + P_{x_h} V_f \frac{\partial x_h}{\partial x_f} - \Lambda_f ' \right) d\Phi(v, \tau) \leq 0 \text{ and} \tag{9}$$

$$x_f \frac{\partial E\pi_f}{\partial x_f} = 0. \tag{10}$$

The second-order condition for the firm is

$$\frac{\partial^2 E\pi_f}{\partial x_f^2} = \int_{v \in R} \left(P_{x_f x_f} V_f + 2P_{x_f x_h} V_f \frac{\partial x_h}{\partial x_f} + P_{x_h} V_f \frac{\partial^2 x_h}{\partial x_f^2} - \Lambda_f '' \right) d\Phi(v, \tau). \tag{11}$$

Given the present assumptions of the model, equation (11) is not guaranteed to be negative. However, assuming equation (11) is negative, a unique maximum exists and is defined by equations (9) and (10) given $x_h(x_f, v)$.

Define x_f^S to be the unique maximum satisfying equations (9) and (10) given $x_h(x_f, v)$. Substituting x_f^S into $x_f(x_f, \varpi_h)$ yields the homeowner's unique equilibrium level of effort, x_h^S. By construction x_f^S and x_h^S satisfy condition (1). Therefore, these equilibrium levels of effort form a unique, perfect Bayesian equilibrium.

Step 3: In the Citizen suit subgame, the homeowner chooses a level of effort and reveals this effort to the firm before the firm chooses its level of effort. Notice that the firm's objective function in equation (2) depends on the homeowner's type only to the extent that the homeowner's type influences the homeowner's level of effort. Given $x_h(\varpi_h)$ is assumed to be irreversible, the only consistent way the firm can update its beliefs is to place a probability of 1.0 on the ϖ_h type homeowner. This belief satisfies condition (2) for a perfect Bayesian equilibrium. A strategy for the firm is to choose a function $x_f(x_h)$ such that $x_f(x_h) \geq 0$. A strategy for the homeowner is to choose x_h given $x_f(x_h)$ such that $x_h \geq 0$.

The firm's objective reduces to

$$Max_{x_f} \ E\pi_f\left(x_f, x_h\right) = P\left(x_f, x_h\right)V_f - \Lambda_f(x_f). \tag{12}$$

The firm's first-order conditions are

$$\frac{\partial E\pi_f}{\partial x_f} = P_{x_f}\left(x_f, x_h\right)V_f - \Lambda_f{}'(x_f) \leq 0 \quad \text{and} \tag{13}$$

$$x_f \frac{\partial E\pi_f}{\partial x_f} = 0 \,. \tag{14}$$

The firm's second-order condition is

$$\frac{\partial^2 E\pi_f}{\partial x_f^2} = P_{x_f x_f}\left(x_f, x_h\right)V_f - \Lambda_f{''}(x_f) < 0 \,. \tag{15}$$

Equation (15) is satisfied by assumption. Therefore, the firm's best response, $x_f(x_h)$, that

satisfies equations (13) and (14) exists and is unique for a given x_h.

Since the homeowner moves first and realizes that the firm will respond according to

$x_f(x_h)$, the homeowner's objective becomes $\underset{x_h}{Max}\ E\pi_h\left(x_f(x_h), x_h\right)$ such that $x_h \geq 0$. The

homeowner's first-order conditions suppressing functional arguments to ease exposition are

$$\frac{\partial E\pi_h}{\partial x_h} = -P_{x_h}V_h - P_{x_f}V_h \frac{\partial x_f}{\partial x_h} - \Lambda_h{'} \leq 0 \text{ and} \tag{16}$$

$$x_h \frac{\partial E\pi_h}{\partial x_h} = 0 \,. \tag{17}$$

The second-order condition for the homeowner is

$$\frac{\partial^2 E\pi_h}{\partial x_h^2} = -P_{x_h x_h}V_h - 2P_{x_h x_f}V_h \frac{\partial x_f}{\partial x_h} - P_{x_f}V \frac{\partial^2 x_f}{\partial x_h^2} - \Lambda_h{''} \,. \tag{18}$$

Given the present assumptions of the model, equation (18) is not guaranteed to be negative.

However, assuming equation (18) is negative, a unique maximum exists and is defined by

equations (16) and (17) given $x_f(x_h)$.

Define x_h^c to be the unique maximum satisfying equations (16) and (17) given $x_f(x_h)$.

Substituting x_h^c into $x_f(x_h)$ yields the firm's unique equilibrium level of effort, x_f^c. By

construction $x_h{}^C$ and $x_f{}^C$ satisfy condition (1) and beliefs satisfy condition (2). Therefore, these

equilibrium levels of effort form a unique, perfect Bayesian equilibrium. Q.E.D.

An Illustration of the Three Second-Stage Subgames

To illustrate the NASH subgame equilibrium, consider Figure 2. The firm's best

response function, F, is denoted as a function of the homeowner's level of effort assuming

linear cost and a ratio contest success function such that $P(x_f, x_h) = x_F / (x_f + x_h)$. For each

homeowner's type ϖ_h, there is an alternative best response function implying a family of best

response functions. A subset of this family of best response functions is denoted by H_1, H_2

and H_3 for a homeowner with benefits V_{h1}, V_{h2} or V_{h3} where $V_{h1} < V_{h2} < V_{h3}$ and $V_{h2} = V_f$.

The homeowner knows her type, and, therefore, knows her actual best response function in

the family of best response functions. The firm knows the homeowner's best response

function given the homeowner's type. If the homeowner's type corresponds to H_1, H_2 or H_3,

then the firm's and homeowner's equilibrium levels of effort given the firm knows the

homeowner's type are $(x_{f1}{}^N, x_{h1}{}^N)$, $(x_{f2}{}^N, x_{h2}{}^N)$ or $(x_{f3}{}^N, x_{h3}{}^N)$. However, the firm must choose its

equilibrium level of effort without the knowing the homeowner's type. $\Phi(v, \tau)$ places a

probability weight on each type of homeowner's best response function. The firm chooses a

level of effort that is the best response to the family of best response functions given $\Phi(v, \tau)$,

for instance $x_f{}^{N*}$. The homeowner responds by choosing a level of effort that is a best

response to $x_f{}^{N*}$ given the homeowner's actual best response function, $x_{h1}{}^{N*}$, $x_{h2}{}^{N*}$ or $x_{h3}{}^{N*}$ for
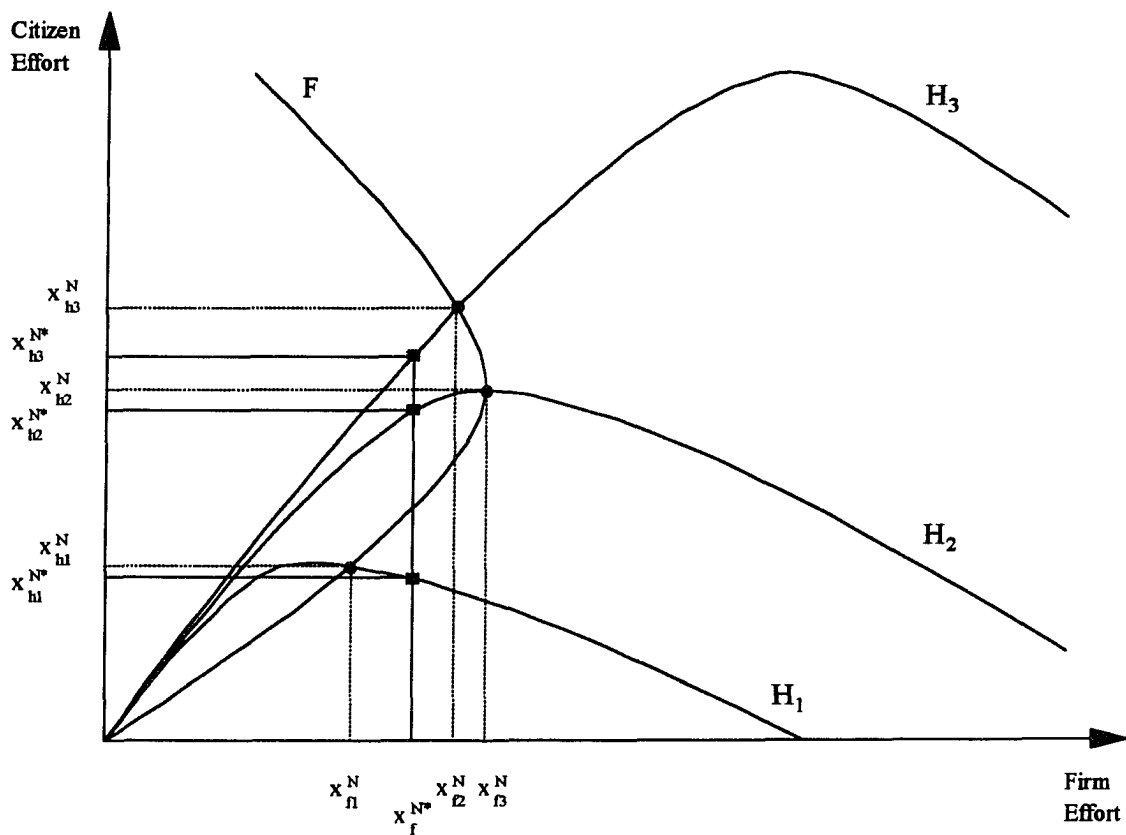
Figure 2: Example of the NASH subgame equilibrium

H_1, H_2 or H_3. These levels of effort represent the perfect Bayesian equilibrium for the alternative homeowner's types in the NASH subgame.

When the firm moves first in the SLAPP subgame, the firm chooses a level of effort knowing that the homeowner will respond according to her best response function. Figure 3 characterizes these equilibria for the three alternative homeowners' types. That is, if the firm knew the homeowner's type corresponded to V_{h1}, V_{h2}, or V_{h3}, then the firm's equilibrium level of effort would be x_{f1}^S, x_{f2}^S or x_{f3}^S and the homeowner would respond with x_{h1}^S, x_{h2}^S or x_{h3}^S.[9] However, since the firm only knows the probability of each type of homeowner, the firm must choose a level of effort that is a best response to all homeowners' types given $\Phi(v,\tau)$. For instance, x_f^{S*}, to which a homeowner with benefit V_{h1}, V_{h2}, or V_{h3} responds with x_{h1}^S, x_{h2}^S or x_{h3}^S.

Figure 4 illustrates the perfect Bayesian equilibrium for the Citizen suit subgame. When the homeowner moves first in the Citizen suit subgame, the homeowner chooses a level of effort knowing that the firm will respond according to F. Given the homeowner's benefit is V_{h1}, V_{h2}, or V_{h3}, the homeowner chooses an equilibrium level of effort x_{h1}^C, x_{h2}^C or x_{h3}^C, to which the firm responds with x_{f1}^C, x_{f2}^C or x_{f3}^C.[10]

Selection of a Contest Success Function

Proposition 1 establishes the existence of an equilibrium for each of the three alternative second-stage subgames. By imposing additional structure on the model, interesting

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[9] Qualitatively, the positions of these equilibrium points are correct (see Baik and Shogren 1992).
[10] Qualitatively, the positions of these equilibrium points are correct (see Baik and Shogren 1992).
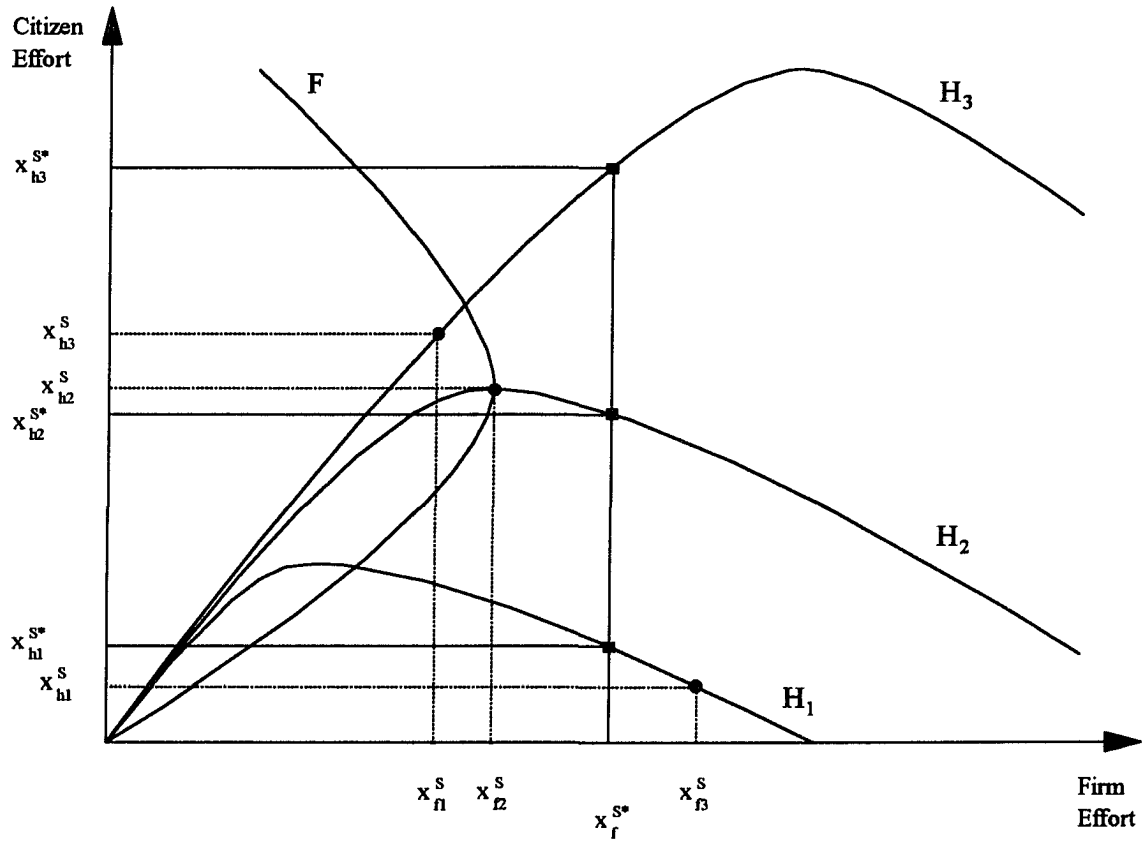
Figure 3: Example of the SLAPP subgame equilibrium
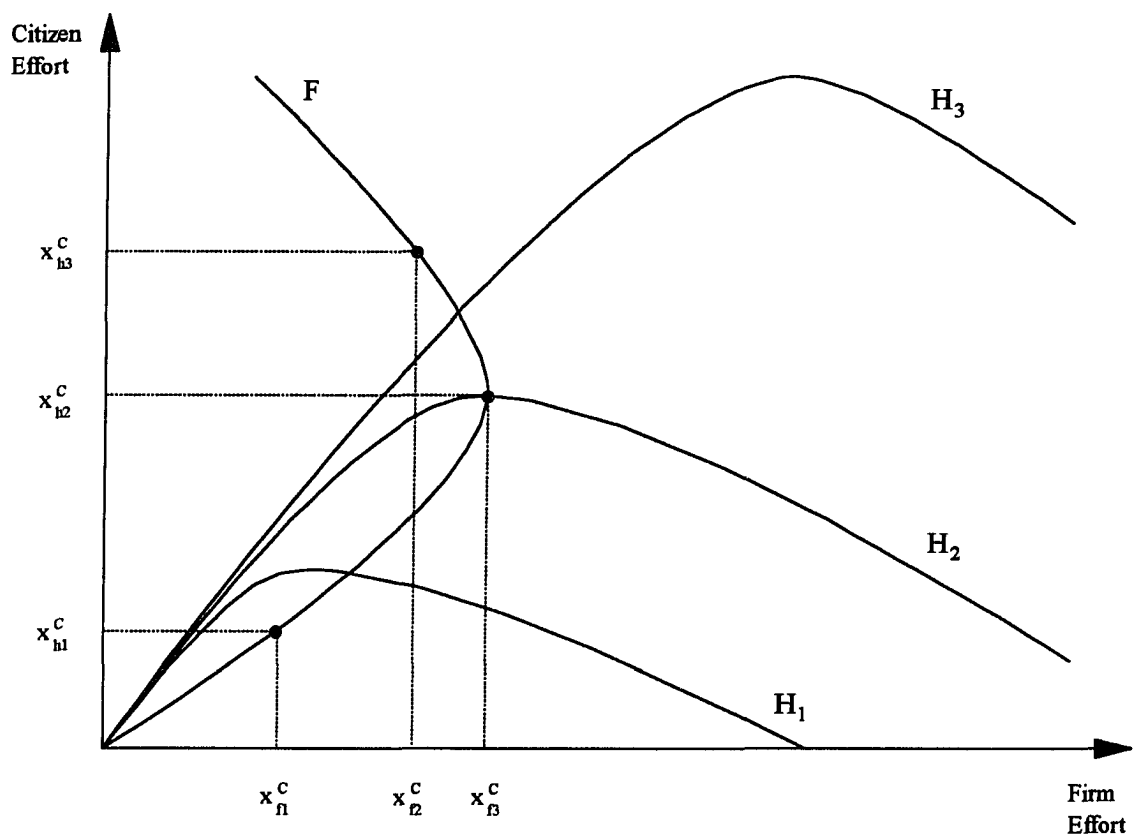
Figure 4: Example of the Citizen suit subgame equilibrium

insights are gained regarding the nature of equilibrium efforts in each of the three alternative

subgames.

Previous investigations of contests have made interesting insights by assuming linear

cost and one of three alternative contest success functions.[11] The first, is the perfectly

discriminating contest success function which has been recently used by Hillman and Riley

(1989), among others, to analyze a contest of asymmetric valuation with complete and two-

sided incomplete information. A simple form of the perfectly discriminating contest success

function is $P(x_f, x_h) = \begin{cases} 1, & \text{for } x_f > x_h \\ \frac{1}{2}, & \text{for } x_f = x_h \\ 0, & \text{for } x_f < x_h \end{cases}$. This contest success function implies that the

agent investing the largest amount of effort guarantees victory. This contest success function

also generally leads to a mixed strategy equilibrium. However, since it is common for agents

to win environmental conflicts even when their effort is surpassed by their opponent's effort,

this contest success function seems inappropriate for the conflict being analyzed here.

One alternative to the perfectly discriminating contest success function is Hirshleifer's

(1989) difference contest success function where a simplified form is

$P(x_f, x_h) = \dfrac{1}{1 + \exp(x_h - x_f)}$. Hirshleifer developed this contest success function to analyze

a contest where both agents invest no effort in equilibrium. Even though an agent invest no

equilibrium effort, the agent still has a positive probability of success. This characteristic

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[11] Linear cost need not be assumed with a suitable transformation of the contest success function. However, specifying a particular contest success function does have implications regarding the cost structure if cost are transformed before the contest success function is specified.

seems inappropriate given the context of the contest presented here because a homeowner

must expend some positive level of effort or forfeit all rights to the firm.

A second alternative to the perfectly discriminating contest success function is

Tullock's (1980) lottery ticket contest success function where each agent can buy as many

lottery tickets as he/she wishes for one dollar a ticket. A ticket is then drawn at random and

the agent who purchased the ticket wins the contest. This contest success function has been

used extensively throughout the literature and recently by Hillman and Riley (1989), Baik

(1994), and Baik and Shogren (1994a), among others, to analyze a contest with asymmetric

valuation, asymmetric ability, and asymmetric reimbursement of effort. A simple form of the

ratio contest success function is $P(x_f, x_h) = \begin{cases} \dfrac{x_f}{x_f + x_h}, & \text{for } x_f > 0 \text{ and } x_h > 0 \\ k, & \text{for } x_f = 0 \text{ and } x_h = 0 \end{cases}$. If neither

agent buys tickets, then the probability that the firm wins is k which is usually set equal to 1/2

for convenience. While this simple ratio contest success function can be generalized as in

Baik (1994), the implications of this type of contest success function are that best response

functions are non-monotonic, and that an equilibrium generally requires at least one agent to

expend a minimal amount of effort. Since the ratio contest success function fits the context of

the model presented here the best and the simplified form has tractable analytic solutions, it is

the specification employed to develop a better understanding of the general model.[12]

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[12] Hillman and Riley (1989) also note that a modified perfectly discriminating contest success function with errors can in some case be reduced to a ratio form.

In its simplest form, Tullock's (1980) ratio contest success function implies that

agent's are equally productive at influencing probabilities. However, this assumption may be

too restrictive as discussed by Baik (1994) and Baik and Shogren (1994a). Define A_i as the

ith agent's productivity of effort, and $\alpha_i = A_i / A_j$ as the ith agent's relative productivity of

effort. Tullock's (1980) ratio contest success function can now be modified and rewritten as

$$P(x_f, x_h) = \frac{A_f x_f}{A_f x_f + A_h x_h} = \frac{x_f}{x_f + \alpha_h x_h}.^{[13]} \quad \text{If } 0 < \alpha_h < 1 \text{, the firm's effort is relatively more}$$

productive. If $\alpha_h > 1$, the homeowner's effort is relatively more productive. If $\alpha_h = 1$, the

homeowner's and firm's efforts are equally productive.

Analytic Solutions for the Ratio Contest Success Function

Given this specification of the contest success function, the firm's and homeowner's

best response functions in Figures 2, 3 and 4 are explicitly characterized. The firm's best

response function is $x_f = \begin{cases} \sqrt{\alpha_h V_f x_h} - \alpha_h x_h, & \text{for } \dfrac{V_f}{\alpha_h} > x_h \\ 0, & \text{for } \dfrac{V_f}{\alpha_h} \leq x_h \end{cases}$ which reaches a maximum at

$x_h = \dfrac{V_f}{4\alpha_h}$. For $0 \leq x_h < \dfrac{V_f}{4\alpha_h}$, the firm's best response function is increasing in the

homeowner's effort. For $\dfrac{V_f}{4\alpha_h} < x_h < \dfrac{V_f}{\alpha_h}$, the firm's best response function is decreasing in

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[13] Since the homeowner never enters this contest unless she is willing to expend some positive level of effort, without loss of generality, the case where both agents employ 0 effort is not considered.

the homeowner's effort. For $x_h \geq \dfrac{V_f}{\alpha_h}$, the firm no longer invests any effort. The

homeowner's best response function is $x_h = \begin{cases} \sqrt{\dfrac{V_h x_f}{\alpha_h}} - \dfrac{x_f}{\alpha_h}, & \text{for } \alpha_h V_h > x_f \\ 0, & \text{for } \alpha_h V_h \leq x_f \end{cases}$ which reaches a

maximum at $x_f = \dfrac{\alpha_h V_h}{4}$. For $0 \leq x_f < \dfrac{\alpha_h V_h}{4}$, the homeowner's best response function is

increasing in the firm's effort. For $\dfrac{\alpha_h V_h}{4} < x_f < \alpha_h V_h$, the homeowner's best response

function is decreasing in the firm's effort. For $x_f \geq \alpha_h V_h$, the homeowner no longer invests

any effort.

These best response functions imply that the perfect Bayesian equilibrium levels of

effort for an interior solution to the NASH subgame are

$$\left[x_f^N, x_h^N \right] = \left[V_f \beta_N (\varpi_h, \alpha_h, \tau)^2, V_h \left(\rho_f \beta_N (\varpi_h, \alpha_h, \tau) - \left(\rho_f \beta_N (\varpi_h, \alpha_h, \tau) \right)^2 \right) \right]$$

where $\rho_f = (\varpi_h \alpha_h)^{-\frac{1}{2}} = \sqrt{\dfrac{V_f A_f}{V_h A_h}}$ and

$$\beta_N (\varpi_h, \alpha_h, \tau) = \dfrac{\int_{\bar{v}_N}^{\hat{\varphi}_N} (v \alpha_h)^{-\frac{1}{2}} d\Phi_N (v, \tau)}{1 + \int_{\bar{v}_N}^{\hat{\varphi}_N} (v \alpha_h)^{-1} d\Phi_N (v, \tau)} = \dfrac{E_{\Phi_N} \left(\rho_f (v) \right)}{1 + E_{\Phi_N} \left(\rho_f (v)^2 \right)}.$$ $\Phi_N(v, \tau)$ represents the firm's

updated beliefs given the NASH subgame is played in the second-stage of the game.[14] The

perfect Bayesian equilibrium levels of effort for an interior solution to the SLAPP subgame

are

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[14] The limits of integration and $\Phi_N(v, \tau)$ are explicitly defined below.

$$\left[x_f^S, x_h^S \right] = \left[V_f \beta_S \left(\varpi_h, \alpha_h, \tau \right)^2, V_h \left(\rho_f \beta_S \left(\varpi_h, \alpha_h, \tau \right) - \left(\rho_f \beta_S \left(\varpi_h, \alpha_h, \tau \right) \right)^2 \right) \right]$$

where $\beta_S \left(\varpi_h, \alpha_h, \tau \right) = \dfrac{\int_{\tilde{v}_S}^{\hat{v}_S} \left(v \alpha_h \right)^{-\frac{1}{2}} d\Phi_S (v, \tau)}{2} = \dfrac{E_{\Phi_S} \left(\rho_F (v) \right)}{2}$. $\Phi_S(v, \tau)$ represents the firm's

updated beliefs given the SLAPP subgame is played in the second-stage of the game.[15] The

perfect Bayesian equilibrium levels of effort for an interior solution to the Citizen suit

subgame are

$$\left[x_h^C, x_f^C \right] = \left[V_h \beta_C \left(\varpi_h, \alpha_h, \tau \right)^2, V_f \left(\rho_h \beta_C \left(\varpi_h, \alpha_h, \tau \right) - \left(\rho_h \beta_C \left(\varpi_h, \alpha_h, \tau \right) \right)^2 \right) \right]$$

where $\rho_h = \sqrt{\varpi_h \alpha_h} = \sqrt{\dfrac{V_h A_h}{V_f A_f}}$ and $\beta_C \left(\varpi_h, \alpha_h, \tau \right) = \dfrac{\sqrt{\varpi_h \alpha_h}}{2} = \dfrac{\rho_h}{2}$.

Define the leader as the agent who strategically commits effort. $\beta_k \left(\varpi_h, \alpha_h, \tau \right)^2$, for k

= S and C, denotes the proportion of the leader's benefit that the leader dissipates in

equilibrium, while $\sqrt{\rho_k} \beta_k \left(\varpi_h, \alpha_h, \tau \right) - \left(\rho_k \beta_k \left(\varpi_h, \alpha_h, \tau \right) \right)^2$ is the follower's best response to

the leader's equilibrium choice of effort. Notice that the proportion of the leader's benefit

dissipated by the leader depends crucially on ρ_k which is denoted as the leader's relative

resolve. The exact specification of the leader's relative resolve is selected to facilitate the

interpretation of the equilibrium efforts in terms of the mean and variance of the leader's

relative resolve.

Notice that for the NASH subgame the structure of the solution is similar to the

structure of the solution in the SLAPP subgame. This result occurs because while the firm's

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[15] The limits of integration and $\Phi_S(v, \tau)$ are explicitly defined below.

and homeowner's equilibrium efforts always fall on the homeowner's best response function they generally fall off the firm's best response function. This result is important because it indicates that the firm's incomplete information places the firm in a leadership role even though the firm is technically not a leader. While the firm's decision is influenced by the general shape of homeowner's best response function, the firm's decision is unaffected by any particular type of homeowner's best response function. Given the homeowner's realized type, the firm's equilibrium choice of effort may be inappropriate *ex post*. In fact, if the firm knew the homeowner's type *ex ante*, this choice of effort would likely be incredible. However, the firm's incomplete information and the homeowner's knowledge of the firm's incomplete information make the firm's equilibrium choice of effort credible even if it is inappropriate *ex post*.

Comparative Static Analysis

Relative resolve which is a composition of both agents' benefits and abilities is an important determinate of each agent's equilibrium behavior. Proposition 2 summarizes the relationships between the agents' relative resolves and the agents' relative benefits and abilities. Proposition 3 and 4 summarize the relationship between the mean and variance of the firm's expected relative resolve and the agents' equilibrium levels of effort. Proposition 5 considers the relationship between the homeowner's realized relative benefit and the agents' equilibrium levels of effort. Proposition 6 considers the relationship between the homeowner's relative ability and the agents' equilibrium levels of effort. These results are derived maintaining the assumptions of linear cost and the ratio form of the contest success function.

Bulow, Geanakoplos, and Klemperer (1985) define an agent's action as a strategic complement (substitute) to another agent if an agent's action increases the marginal payoff of the other agent. The primary result of this section is that while many of the comparative static results are ambiguous in general, these ambiguities are usually resolved based on whether or not the leader's equilibrium effort is a strategic complement or substitute to the follower.

Given the ratio form of the contest success function, the intersection of the firm's and a homeowner's best response functions has specific strategic properties that may not generalize to other specifications of the contest success function.[16] When $\rho_F = \rho_C = 1$, the firm's and homeowner's best response functions intersect at the maximum of both best response functions. For example, consider the intersection of F and H_2 in Figures 2, 3 and 4. When $\rho_F > 1 > \rho_C$, the firm's best response function intersects the homeowner's best response function where the firm's best response function is increasing and the homeowner's best response function is decreasing. For example, consider the intersection of F and H_1 in Figures 2, 3 and 4. When $\rho_C > 1 > \rho_F$, the firm's best response function intersects the homeowner's best response function where the firm's best response function is decreasing and the homeowners best response function is increasing. For example, consider the intersection of F and H_3 in Figures 2, 3 and 4. This implies that the homeowner's relative resolve is increasing from H_1 to H_3 and that when one agent's equilibrium effort is a strategic complement in the NASH subgame the other agent's equilibrium effort must be a strategic substitute.

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[16] These properties can be verified by examining the solution to the firm's and the a homeowner's best response functions.

Proposition 2: The ith agent's relative resolve is increasing in the ith agent's relative ability and relative benefit.[17]

An agent's relative resolve is best interpreted as a measure of an agent's relative strength. This relative strength is composed of two distinct elements. The first element represents how "bad" an agents wants to win the contest relative to her opponent, while the second element represents the agent's natural ability to win the contest relative to her opponent. Together both elements determine how much effort an agent invest to win the contest. As an agent's relative benefit or relative ability increase, the agent's relative strength increases and relative resolve increases.

Proposition 3: Assume that increasing τ increases the mean of the firm's expected resolve while maintaining the variance. If the firm's equilibrium effort is a strategic complement (substitute) to the homeowner

a)   in the SLAPP subgame, the firm's equilibrium effort is increasing in τ, while the homeowner's equilibrium effort is increasing (decreasing) in τ.

b)   in the NASH subgame, the firm's equilibrium effort is increasing in τ as

$1 > 2E_{\Phi_N}\left(\rho_f\right)\beta_N\left(\varpi_h, \alpha_h, \tau\right)$ and decreasing in τ as

$1 < 2E_{\Phi_N}\left(\rho_f\right)\beta_N\left(\varpi_h, \alpha_h, \tau\right)$. When the firm's equilibrium effort is

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[17] For the proof of proposition 2, see Appendix A.

increasing, the homeowner's equilibrium effort is increasing (decreasing), while when the firm's equilibrium effort is decreasing, the homeowner's equilibrium effort is decreasing (increasing).[18]

Recall that in Figures 2 and 3 the firm's beliefs place a probability weight on each type of homeowner's best response function. The direct effect of a variance preserving mean increase in the firm's expected resolve is to increase the likelihood of homeowners' types with low relative resolve. For instance, the likelihood of H_1 and H_2 increases, while the likelihood of H_3 decreases. Increasing τ does not directly alter either the firm's or homeowner's best response functions. However, the increase in τ indirectly affects the firm's equilibrium effort by making homeowners' types with lower relative resolve more likely. This indirect effect on the firm's equilibrium effort then spills over to the homeowner as the homeowner chooses her best response to the firm's equilibrium effort.

In Figure 3, notice that when the firm's information is complete the lower the homeowner's relative resolve the greater the firm's equilibrium effort, $x_{f1}^S > x_{f2}^S > x_{f3}^S$. Therefore, when the firm's information is incomplete and homeowners' types with low relative resolve become more likely, the firm's equilibrium effort, x_f^{S*}, increases. If the firm's equilibrium effort falls on an increasing (decreasing) portion of the homeowner's actual best response function, H_3 (H_1 and H_2), then the homeowner increases (decreases) her equilibrium effort in response to the firm's increased equilibrium effort.

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[18] For the proof of proposition 3, see Appendix A.

Notice in Figure 2 that when the firm's information is complete the firm's equilibrium

effort is increasing (decreasing) in the firm's relative resolve as the homeowner's best

response function intersects a decreasing (increasing) portion of the firm's best response

function, $x_{f3}^N > x_{f2}^N$ ($x_{f3}^N > x_{f1}^N$). Therefore, when information is incomplete and homeowners'

types with low relative resolve become more likely, the firm has the incentive to increase its

equilibrium effort as homeowners' types like H_2 become more likely, and to decrease its

equilibrium effort as homeowners' types like H_1 become more likely. The net effect is that the

firm's equilibrium effort increases (decreases) as the firm expects that the homeowner's

equilibrium effort is on an increasing (decreasing) portion of the firm's best response function

or as $1 > (<)2E_{\Phi_N}(\rho_F)\beta_N(\varpi_C, \alpha_C, \tau)$. When the firm's expectations lead to an increase in

the firm's equilibrium effort, the homeowner decreases (increases) her equilibrium effort if the

firm's equilibrium effort falls on a decreasing (increasing) portion of the homeowner's best

response function, H_1 (H_2 and H_3). When the firm's expectations lead to a decrease in the

firm's equilibrium effort, the homeowner increases (decreases) her equilibrium effort if the

firm's equilibrium effort falls on a decreasing (increasing) portion of the homeowner's best

response function.

Proposition 4: Assume that increasing τ increases the variance of the firm's expected relative

resolve while maintaining the mean. In the NASH subgame, the firm's equilibrium effort is

decreasing in τ, and the homeowner's equilibrium effort is increasing (decreasing) in τ as the firm's equilibrium effort is a strategic substitute (complement) to the homeowner.[19]

In this instance, an increase in τ redistributes probability weights towards homeowners' types with relatively low and relatively high relative resolve. For example, in Figures 2 and 3, H_1 and H_3 become more likely, while H_2 becomes less likely. Otherwise, the firm's and homeowner's best response functions are unchanged.

In the SLAPP subgame, as homeowners' types with low relative resolve become more likely, the firm has the incentive to increase its equilibrium effort, while, as homeowners' types with high relative resolve become more likely, the firm has the incentive to decrease its equilibrium effort. Given the specific definition of the firm's relative resolve, the firm's incentives exactly offset one another and there is no net change in the firm's equilibrium effort. Since the firm's equilibrium effort is unaffected, the homeowner has no incentive to alter her equilibrium effort.

In the NASH subgame, the firm has the incentive to decrease its equilibrium effort as homeowners' type with high and low relative resolve become more likely. Therefore, the firm's equilibrium effort unambiguously decreases. Since the firm decreases its equilibrium effort, the homeowner increases (decreases) her equilibrium effort if the firm's equilibrium effort falls on a decreasing (increasing) portion of the homeowner's best response function.

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[19] For the proof of proposition 4, see Appendix A.

Proposition 5: In any of the three alternative subgames, the homeowner's equilibrium effort is increasing in the homeowner's relative benefit. In the Citizen suit subgame, the firm's equilibrium effort is increasing (decreasing) in the homeowner's relative benefit as the homeowner's equilibrium effort is a strategic complement (substitute) to the firm. In the SLAPP and NASH subgames, the firm's equilibrium effort is independent of the homeowner's relative benefit.[20]

The larger the homeowner's realized relative benefit, the higher the homeowner's best response function. As seen in Figures 2, 3 and 4, the higher the homeowner's best response function the greater the homeowner's equilibrium effort for any given level of firm effort. When the firm does not know the homeowner's type as in the SLAPP and NASH subgames, the firm's equilibrium effort is independent of the homeowner's realized relative benefit. When the firm does not know the homeowner's type, but does know the homeowner's equilibrium effort as in the Citizen suit subgame, the firm's equilibrium effort increases (decreases) as the homeowner's equilibrium effort falls on an increasing (decreasing) portion of the firm's best response function.

Proposition 6: As the homeowner's relative ability increases, if the leader's equilibrium effort is a strategic complement (substitute) to the follower

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[20] For the proof of proposition 5, see Appendix A.

a)   in the SLAPP subgame, the firm's equilibrium effort is decreasing, while

the homeowner's equilibrium effort is decreasing (increasing).

b)   in the NASH subgame where the firm is defined as the leader, the firm's

equilibrium effort is increasing as $E_{\Phi_N}\left(\rho_f^2\right) > 1$ and decreasing as

$E_{\Phi_N}\left(\rho_f^2\right) < 1$. The homeowner's equilibrium effort is decreasing

(increasing).

c)   in the Citizen suit subgame, the homeowner's equilibrium effort is

increasing, while the firm's equilibrium effort is increasing (decreasing).[21]

The direct effect of increasing the homeowner's relative ability is to lower the firm's

best response function and to fan the family of homeowners' best response functions upward.

While the likelihood of each homeowner's best response function is unchanged, the increase in

the homeowner's relative resolve indirectly decreases the mean and variance of the firm's

expected relative resolve.

In the SLAPP subgame, the direct and indirect effect unambiguously decrease the

firm's equilibrium effort. While both the direct and indirect effects on the homeowner's

equilibrium effort are ambiguous in general, both effects depend on whether the firm's

equilibrium effort falls on an increasing or decreasing portion of the homeowner's best

response function. If the firm's equilibrium effort falls on an increasing (decreasing) portion

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[21] For the proof of proposition 6, see Appendix A.

of the homeowner's best response function, the homeowner decreases (increases) her equilibrium effort as the firm's equilibrium effort decreases.

In the NASH subgame, the direct and indirect mean effect tend to increase (decrease) the firm's equilibrium effort as the firm expects that the homeowner's equilibrium effort falls on an increasing (decreasing) portion of the firm's best response function. The indirect variance effect tends to increase the firm's equilibrium effort. The net effect on the firm's equilibrium effort is positive (negative) as $E_{\Phi_N}\left(\rho_F^{\ 2}\right) > (<)1$. The direct effect on the homeowner's equilibrium effort is negative (positive) as the firm's equilibrium effort falls on an increasing (decreasing) portion of the homeowner's best response function. The indirect effect on the homeowner's equilibrium effort depends on whether the net effect on the firm's equilibrium effort is positive or negative and whether the firm's equilibrium effort falls on an increasing or decreasing portion on the homeowner's best response function. Since the direct effect always dominates the indirect effect, the net effect on the homeowner's equilibrium effort is negative (positive) as the firm's equilibrium effort falls on an increasing (decreasing) portion of the homeowner's best response function.

As the increase in the homeowner's relative ability increases the homeowner's relative resolve, the homeowner increases her equilibrium effort in the Citizen suit subgame. If the homeowner's equilibrium level of effort falls on an increasing (decreasing) portion of the firm's best response function, the firm responds by increasing (decreasing) its equilibrium effort.

THE PERFECT BAYESIAN EQUILIBRIUM IN THE FORMAL MODEL FOR THE RATIO CONTEST SUCCESS FUNCTION

The previous chapter derived the perfect Bayesian equilibrium for the three alternative

subgames assuming linear cost and a ratio contest success function. In this section, the

assumptions of linear cost and the ratio contest success function are maintained and two

classes of perfect Bayesian equilibria for the SLAPP game with and without the SLAPP action

are characterized. Below, the SLAPP game without the SLAPP action is referred to as the

SLAPP-free game. The first class considers equilibria where there is 0 probability that the

firm will ever witness the homeowner Squawk. In this class, Bayes rule can not be applied to

update the firm's beliefs. The second class of equilibria considers cases where there is a

positive probability that the homeowner chooses Squawk. In this class, Bayes rule is used to

update the firm's beliefs. Proposition 7 shows that the firm always prefers the SLAPP

subgame to the NASH subgame. Proposition 8 characterizes the first class of equilibria when

the SLAPP or NASH subgame is played given the homeowner chooses Squawk. Proposition

9 characterizes the second class of equilibria when the SLAPP or NASH subgame is played

given the homeowner chooses Squawk. The primary result of this section is that agents'

equilibrium behaviors are driven by relative resolve. For a given relative resolve, the

proportion of relative resolve attributable to the agent's relative benefit or ability is irrelevant.

Proposition 7: For any set of updated beliefs given the homeowner chooses Squawk, the

firm always, at least weakly, prefers the SLAPP action to the NASH action.[22]

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[22] For the proof of proposition 7, see Appendix A.

The only difference for the firm between the SLAPP and NASH subgames is that the firm moves first in the SLAPP subgame. Since the firm can always choose an equilibrium level of effort in the SLAPP subgame that will lead to an equilibrium identical to the NASH subgame, the firm is always able to guarantee a payoff in the SLAPP subgame that is at least as large as its payoff in the NASH subgame. Proposition 7 is a strong result that implies that a firm will always choose SLAPP given the homeowner chooses Squawk. Therefore, eliminating the SLAPP action will have a significant impact on equilibrium behavior because the firm will no longer be able to exercise its preferred action.

Proposition 8: Assume that the kth subgame is played for k = S or N, and that the firm's off the equilibrium path, updated beliefs, $\Phi_k(v, \tau)$, are such that $\beta_k(\varpi_h, \alpha_h, \tau) > \frac{1}{2}$ given the homeowner chooses Squawk. The following sequence of play is a perfect Bayesian equilibrium for the game:

- the homeowner chooses Sue and strategically commits a level of effort x_h^C,

- the firm responds with a level of effort x_f^C given x_h^C.[23]

Proposition 7 implies that in the SLAPP game the firm always chooses SLAPP given the homeowner chooses Squawk. When the SLAPP action is eliminated in the SLAPP-free game, the firm is constrained to choose NASH given the homeowner chooses Squawk. Proposition 8 summarizes the necessary and sufficient condition for a pooling equilibrium

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[23] For the proof of proposition 8, see Appendix A.

where all homeowners' types choose Sue for either the SLAPP or SLAPP-free game.

Technically, this equilibrium is not unique because any $\Phi(v, \tau)$ that can be defined to satisfy

$\beta_k(\varpi_h, \alpha_h, \tau) > \dfrac{1}{2}$ represents a different off the equilibrium path belief that supports this class

of pooling equilibrium. However, since both agents' equilibrium efforts are independent of

$\beta_k(\varpi_h, \alpha_h, \tau)$, any two alternative equilibrium beliefs satisfying $\beta_k(\varpi_h, \alpha_h, \tau) > \dfrac{1}{2}$ lead to

identical equilibrium efforts.[24] Given the uniqueness of equilibrium behavior under a multitude

of possible equilibrium beliefs, this equilibrium is loosely referred to as unique.

Proposition 9: Assume that the kth subgame is played for k = S or N and that the firm's

updated beliefs, $\Phi_k(v, \tau)$, are such that $\beta_k(\varpi_h, \alpha_h, \tau) \leq \dfrac{1}{2}$ given the homeowner chooses

Squawk. The following sequence of play is a perfect Bayesian equilibrium for the game:

- If $0 < \varpi_h < \breve{v}_k$ or $\varpi_h > \hat{v}_k$, the homeowner chooses Sue and strategically

commits a level of effort $x_h{}^C$. The firm responds by selecting a level of effort $x_f{}^C$

given $x_h{}^C$.

- If $\breve{v}_k \leq \varpi_h \leq \hat{v}_k$, the homeowner chooses Squawk. The firm updates its beliefs

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[24] A unique equilibrium belief can be established by refining the perfect Bayesian equilibrium concept. One such refinement that would imply a unique equilibrium belief such that $\beta_k(\varpi_h, \alpha_h, \tau) = 1/2$ is the concept of universal divinity [see Banks, Camerer and Porter (1994) for a brief and intuitive primer on equilibrium refinements for games of incomplete information]. This belief implies that all homeowners' types choose Sue except for the type whose relative resolve is equal to 1. This type is indifferent between Sue and Squawk. If this type chooses Sue, then a unique universally divine equilibrium exists. However, since this type is assumed to choose Squawk, no universally divine equilibrium exists.

$$\text{such that } \Phi_k(v,\tau) \equiv \begin{cases} 0, & \text{for } \varpi_h < \breve{v}_k \\ \dfrac{G(v,\tau) - G(\breve{v}_k,\tau)}{G(\hat{v}_k,\tau) - G(\breve{v}_k,\tau)}, & \text{for } \breve{v}_k \leq \varpi_h \leq \hat{v}_k \\ 1, & \text{for } \hat{v}_k < \varpi_h \end{cases} \text{. The firm chooses a}$$

level of effort x_f^k, and the homeowner chooses a level of effort x_h^k.[25]

Proposition 9 summarizes behavior for a partially separating equilibrium in the SLAPP

and SLAPP-free games where one set of homeowners' types chooses Sue, and the

complementary set chooses Squawk. For a partially separating equilibrium to exist, Bayes

rule must define the firm's updated beliefs such that $\beta_k(\varpi_h, \alpha_h, \tau) \leq \dfrac{1}{2}$. Given the possible

nonlinear nature of $\Phi(v, \tau)$ and $\beta_k(\varpi_h, \alpha_h, \tau)$ there is no guarantee that a solution exists.

Assuming a solution does exist, there is no *a priori* reason to suspect that the solution is

unique. Multiple equilibria in this case are more troublesome because both agents' equilibrium

efforts may depend on the firm's updated beliefs implying that different equilibrium beliefs

may lead to different equilibrium levels of effort.

In Figures 5 (a) and 6 (a), Δ_S and Δ_N represent the difference in the homeowner's

expected payoffs from choosing Squawk as opposed to Sue for the SLAPP and SLAPP-free

games. The general form of Δ_S and Δ_N is summarized by $\Delta_k(\rho_h)$ from equation A3 in

Appendix A. In the SLAPP game, when Δ_S is positive for a given homeowner's type, the

homeowner chooses Squawk and the firm responds with SLAPP. If Δ_S is negative, the

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[25] For the proof of proposition 9, see Appendix A.

homeowner chooses Sue. In the SLAPP-free game, when Δ_N is positive for a given homeowner's type, the homeowner chooses Squawk and the firm is constrained to choose NASH. If Δ_N is negative, the homeowner chooses Sue.

Δ_S and Δ_N are identical quadratic forms with the exception of the constant term. For Δ_S, the constant term is $\beta_S(\varpi_h, \alpha_h, \tau)$, while for Δ_N, the constant term is $\beta_N(\varpi_h, \alpha_h, \tau)$. When $\beta_S(\varpi_h, \alpha_h, \tau) > \beta_N(\varpi_h, \alpha_h, \tau)$, Δ_N is above Δ_S for all homeowners' types. The set of homeowners' types that choose Squawk in the SLAPP game is contained by the set of homeowners' types that choose Squawk in the SLAPP-free game. This implies that the availability of the SLAPP action encourages a larger set of homeowners' types to reveal themselves to the firm by strategically committing effort. When $\beta_S(\varpi_h, \alpha_h, \tau) > \beta_N(\varpi_h, \alpha_h, \tau)$, Δ_S is above Δ_N for all homeowners' types. The set of homeowners' types that choose Squawk in the SLAPP-free game is contained by the set of homeowners' types that choose Squawk in the SLAPP game. In this event, the availability of the SLAPP action encourages a smaller set of homeowners' types to reveal themselves to the firm by strategically committing effort. When $\beta_N(\varpi_h, \alpha_h, \tau) = \beta_S(\varpi_h, \alpha_h, \tau)$, Δ_S is identical to Δ_N and the elimination of the SLAPP action has no effect on the set of homeowners' types that choose to reveal themselves to the firm by strategically committing effort.

Dixit (1987) defined an agent as a favorite (underdog) if the agent had a probability of winning greater (less) than 1/2 in the Nash equilibrium.[26] Baik and Shogren (1992) demonstrate that in a general contest with complete information and endogenous timing

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[26] In its original context, the Nash equilibrium is synonymous with the NASH subgame equilibrium.
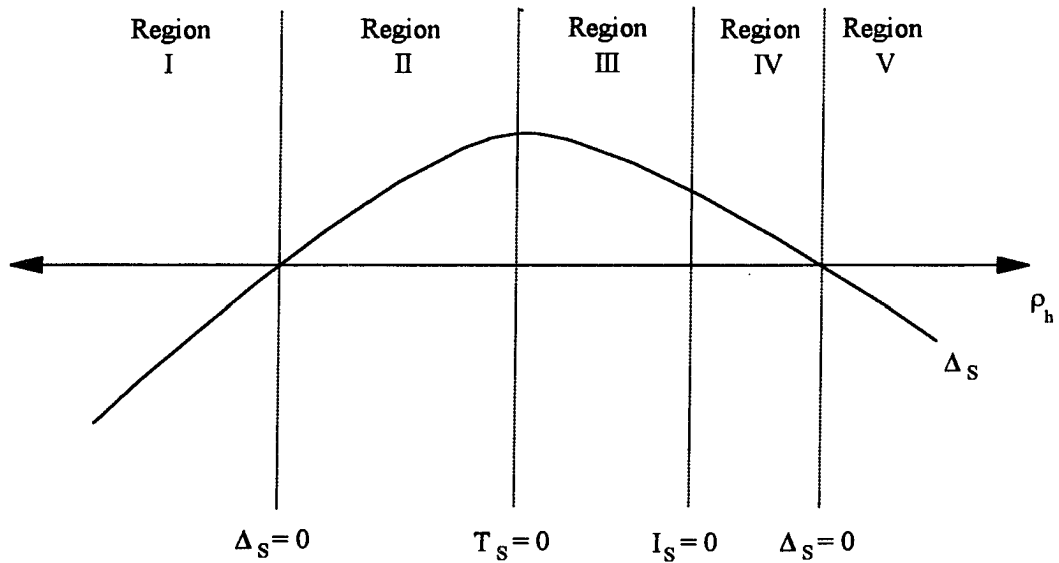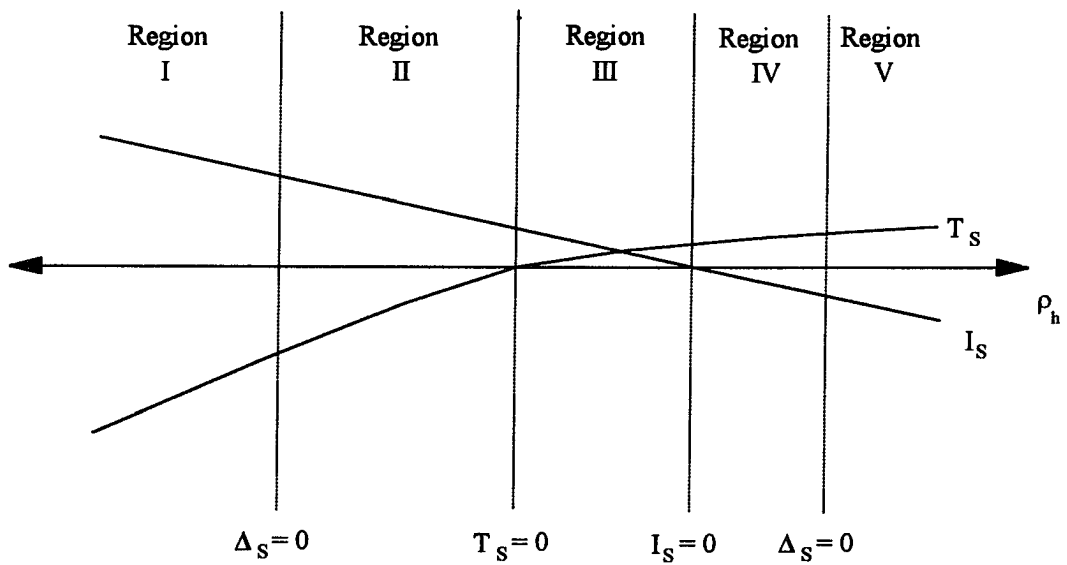
Figure 5: (a) The homeowner's expected payoff from choosing Squawk minus the
homeowner's expected payoff from choosing Sue in the SLAPP game
(b) Information and timing effects in the SLAPP game

Region I | Region II | Region III | Region IV | Region V

$I_N = 0$ $\Delta_N = 0$ $\Delta_N = 0$ $I_N = 0$

ρ_h

Δ_N

(a)

Region I | Region II | Region III | Region IV | Region V

$I_N = 0$ $\Delta_N = 0$ $\Delta_N = 0$ $I_N = 0$

I_N ρ_h

T_N
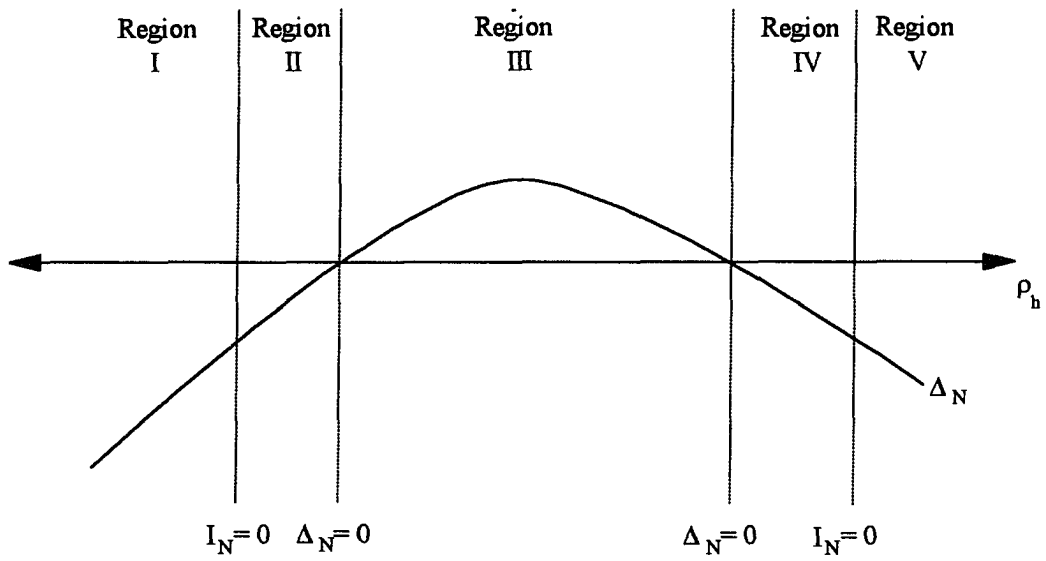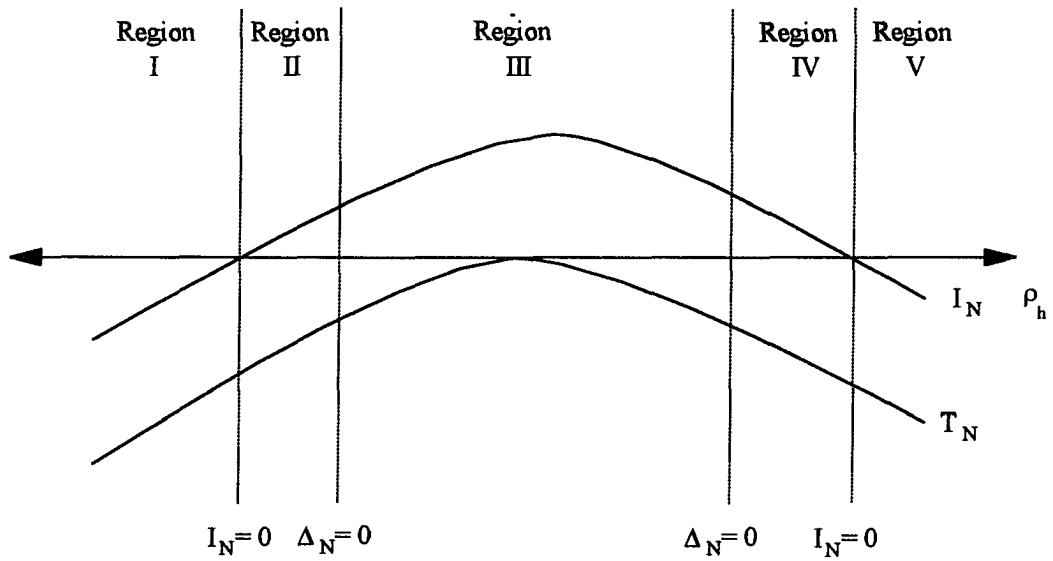
(b)

Figure 6: (a) The homeowner's expected payoff from choosing Squawk minus the homeowner's expected payoff from choosing Sue in the SLAPP-free game
(b) Information and timing effects in the SLAPP-free game

underdogs choose to lead and strategically commit effort, while the favorites choose to

follow. An important implication of propositions 7, 8, and 9 is that some complete

information favorites (underdogs) may choose to lead (follow) when information is incomplete

and asymmetric.[27]

To obtain a better understanding of the effect of asymmetric incomplete information

on the homeowner's timing decision in this contest, it is useful to decompose the

homeowner's decision into an information effect and a timing effect. Assume that the kth

subgame is played given the homeowner chooses Squawk where k = S or N. Define I_k as the

homeowner's expected payoff in the kth subgame assuming incomplete information minus the

homeowner's expected payoff in the kth subgame assuming complete information. Define T_k

as the homeowner's expected payoff in the kth subgame assuming information is complete

minus the homeowner's expected payoff in the Citizen suit subgame. I_k is the information

effect and represents difference in the homeowner's expected payoff in the kth subgame due

to the firm's incomplete information. T_k is the timing effect and represents the difference in

the homeowner's expected payoff due to choosing Squawk instead of Sue assuming the firm's

information is complete. By construction $\Delta_k = I_k + T_k$.

First, consider the SLAPP game where k = S. Figure 5 (b) depicts a qualitatively

accurate graphical representation of I_S and T_S over the interesting range.[28] By allowing the

firm's beliefs to degenerate it can be shown that

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[27] Baik and Shogren's (1992) timing decisions were modeled more generally, so their result certainly applies to the model presented here.

[28] The interesting range is the range where an interior solution exist for both the Citizen suit and SLAPP subgames with both complete and incomplete information.

$$I_S = V_h \left[\left(1 - \rho_f \beta_S \right)^2 - \left(1 - \rho_f \beta_S{}' \right)^2 \right]$$

and

$$T_S = V_h \left[\left(1 - \rho_f \beta_S{}' \right)^2 - \left(\rho_f \beta_c - \beta_c{}^2 \right) \right]$$

where functional arguments have been omitted to ease exposition and $\beta_S{}' = \dfrac{\rho_f}{2}$.

Rearranging term's and substituting, it can be shown that $I_S >(<) \, 0$ as $\beta_S{}' > (<)\beta_S$ or as

$\rho_f > (<)E_{\Phi_S}\left(\rho_f(v) \right)$, and $T_S >(<) \, 0$ as $\rho_h >(<) \, 1$ over the relevant range. Furthermore, it can

be shown that when information is assumed to be complete the homeowner is a favorite

(underdog) as $\rho_h >(<) \, 1$.

In Figure 5(a), Region I, $\rho_f > E_{\Phi_S}\left(\rho_f(v) \right)$, $\rho_h < 1$ and $\Delta_S < 0$. Since

$\rho_f > E_{\Phi_S}\left(\rho_f(v) \right)$, the information effect is positive and the firm's actual relative resolve is

higher than expected. Since $\rho_h < 1$, the timing effect is negative and the homeowner is an

underdog. $\Delta_S < 0$ implies that the positive information effect is dominated by the negative

timing effect. Intuitively, given that the homeowner has low relative resolve, the

homeowner's initial inclination is to Sue and strategically commit a low level of effort to

minimize the firm's commitment of effort. However, if the homeowner chooses Squawk

instead, the firm expects that the homeowner's relative resolve is higher than it actually is.

The firm commits less effort in the SLAPP subgame than if it knew the homeowner's actual

relative resolve making the SLAPP subgame more attractive to the homeowner. In this

region, while the SLAPP subgame is more attractive, the homeowner's payoff is still higher in the Citizen suit subgame so the homeowner chooses Sue.

In Region II, $\rho_f > E_{\Phi_s}\left(\rho_f(v)\right)$, $\rho_h < 1$, and $\Delta_S > 0$. As before, the firm's actual relative resolve is higher than expected, and the homeowner is an underdog. However, since $\Delta_S > 0$, the positive information effect now dominates the negative timing effect. As before, the homeowner's initial inclination is to Sue. But again, if the homeowner chooses Squawk instead, the firm will use less effort in the SLAPP subgame than if it knew the homeowner's true resolve. In this region, the firm's *ex ante* belief that the homeowner's relative resolve is higher than it actually is makes the SLAPP subgame more attractive to the homeowner than the Citizen suit subgame such that the homeowner chooses Squawk.

In Region III, $\rho_f > E_{\Phi_s}\left(\rho_f(v)\right)$, $\rho_h > 1$, and $\Delta_S > 0$. The firm's actual relative resolve is still higher than expected, but since $\rho_h > 1$, the homeowner is a favorite instead of an underdog. Δ_S is unambiguously greater than 0 because both the information and timing effects are positive. The information effect is positive because the firm uses less effort in the SLAPP subgame than if it knew the homeowner's actual relative resolve. The timing effect is positive because the homeowner has the incentive to allow the firm to strategically commit a low level of effort to minimize the homeowner's commitment of effort. Together, the two effects complement each other and the homeowner chooses Squawk.

In Region IV, $\rho_f < E_{\Phi_s}\left(\rho_f(v)\right)$, $\rho_h > 1$, and $\Delta_S > 0$. Now, since $\rho_f < E_{\Phi_s}\left(\rho_f(v)\right)$, the firm's actual relative resolve is lower than expected. This leads to a negative information effect as the firm invest more effort in the SLAPP subgame than if it knew the homeowner's

actual relative resolve. Since the homeowner is still a favorite, the timing effect is positive.

$\Delta_S > 0$ implies that the positive timing effect dominates the negative information effect.

Intuitively, the homeowner's initial inclination is to let the firm strategically commit effort.

However, the firm's incomplete information leads the firm to invest more effort than it would

otherwise. While this discourages the homeowner from choosing Squawk, it is still preferable

for the homeowner to choose Squawk and adjust to the firm's excess effort.

In Region V, $\rho_f < E_{\Phi_s}\left(\rho_f(v)\right)$, $\rho_h > 1$, and $\Delta_S < 0$. The information effect is

negative and the timing effect is positive. $\Delta_S < 0$ implies that the negative information effect

dominates the positive timing effect. Now, as the firm grossly over estimates its actual

relative resolve, the additional effort employed by the firm due to this over estimate is enough

to convince the homeowner to give up any benefit from allowing the firm to strategically

commit effort. The homeowner chooses to immediately reveal her actual relative resolve to

the firm by strategically committing her own effort.

Now, consider the SLAPP-free game where k = N. Figure 6 (b) depicts a qualitatively

accurate graphical representation of I_N and T_N over the interesting range.[29] By allowing the

firm's beliefs to degenerate it can be shown that

$$I_N = V_h\left[\left(1 - \rho_f\beta_N\right)^2 - \left(1 - \rho_f\beta_N'\right)^2\right]$$

and

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[29] The interesting range is the range where an interior solution exist for both the Citizen suit and NASH subgames with both complete and incomplete information.

$$T_N = V_h\left[\left(1-\rho_f\beta_N{}'\right)^2 - \left(\rho_f\beta_c - \beta_c{}^2\right)\right]$$

where $\beta_N{}' = \dfrac{\rho_f}{1+\rho_f{}^2}$. Rearranging term's and substituting, it can be shown that $I_N >(<)$ 0 as

$\beta_N{}' > (<)\beta_N$ and $T_S \le 0$. Furthermore, it can be shown that $\beta_N{}' > \beta_N$ when

$$\left(2\beta_N\right)^{-1} - \sqrt{\left(2\beta_N\right)^{-2}-1} < \rho_h < \left(2\beta_N\right)^{-1} + \sqrt{\left(2\beta_N\right)^{-2}-1} \text{ and that } \beta_N{}' < \beta_N \text{ when}$$

$$\rho_h < \left(2\beta_N\right)^{-1} - \sqrt{\left(2\beta_N\right)^{-2}-1} \text{ or } \rho_h > \left(2\beta_N\right)^{-1} + \sqrt{\left(2\beta_N\right)^{-2}-1}.$$

In Figure 6 (a), Regions I and V, $T_N < 0$, $I_N < 0$ and $\Delta_N < 0$. T_S is always less than or equal to 0 because when information is complete, the homeowner can always strategically commit a level of effort that will lead to an equilibrium identical to the NASH subgame equilibrium. Therefore, the homeowner can guarantee a payoff in the Citizen suit subgame that is at least as great as her payoff in the complete information NASH subgame. $I_N < 0$ implies $\beta_N{}' < \beta_N$. $\beta_N{}' < \beta_N$ implies that the firm invest more equilibrium effort in the NASH subgame when information is incomplete than if it knew the homeowner's actual relative resolve. Since the timing effect is less than or equal to 0, the homeowner's initial inclination is to choose Sue. If the homeowner were to choose Squawk instead, the firm's incomplete information causes the firm to fight harder which discourages the homeowner from choosing Squawk. Δ_N is unambiguously less than 0 since both the timing and information effects discourage the homeowner from choosing Squawk.

In Regions II and IV, $T_N < 0$, $I_N > 0$ and $\Delta_N < 0$. The timing effect is negative, while the information effect is positive. The information effect is positive because $I_N > 0$ implies

$\beta_N' > \beta_N$. $\beta_N' > \beta_N$ implies that the firm invest less equilibrium effort in the NASH subgame when information is incomplete than if it knew the homeowner's actual relative resolve. The homeowner's initial inclination is to Sue because of the negative timing effect. However, if the homeowner chooses Squawk instead, the firm does not fight as hard as if it knew the homeowner's actual relative resolve. $\Delta_N < 0$ implies the negative timing effect dominates the positive information effect, and even though the firm does not fight as hard in the incomplete information NASH subgame, the firm's reduced equilibrium effort is not enough to outweigh the homeowner's initial inclination to Sue.

In Region III, $T_N \leq 0$, $I_N > 0$ and $\Delta_N > 0$. As in Region II and IV, the timing effect and the information effect work against each other. $\Delta_N > 0$ implies that the information effect dominates the timing effect. The homeowner's initial inclination to Sue is more than offset by the reduction in the firm's equilibrium effort in NASH subgame when information is incomplete. This leads to the homeowner to choose Squawk instead of Sue.

EFFICIENCY AND THE ELIMINATION OF STRATEGIC LAWSUITS AGAINST PUBLIC PARTICIPATION FOR THE RATIO CONTEST SUCCESS FUNCTION

Equilibrium behavior is determined by relative resolve and the accuracy of the firm's assessment of relative resolve given its incomplete information.[30] In this chapter, the efficiency consequences of asymmetric incomplete information and the elimination of SLAPPs is investigated. First, *ex post* efficiency is considered, followed by *ex ante* efficiency. The primary result of this chapter is that the difference in efficiency between the SLAPP and SLAPP-free games is in general ambiguous. However, this difference depends crucially on expected relative resolve, actual relative resolve and the composition of relative resolve in terms of relative benefits and abilities. Parameterizations of the SLAPP and SLAPP-free game assuming the homeowners' types are uniformly and normally distributed suggest that the SLAPP game is always at least as efficient as the SLAPP-free game.

Efficiency Defined

The traditional measure of efficiency in a contest is rent dissipation which is defined as the value of resources spent contesting the prize. However, rent dissipation may be a misleading measure of efficiency in a contest with asymmetric valuation (see Appendix B). Given that the SLAPP and SLAPP-free games are contests with asymmetric valuation, contest efficiency is used, as defined in Appendix B, as the primitive measure of efficiency.

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[30] Relative resolve is referred to as being unique because the homeowner's relative resolve is the inverse of the firm's relative resolve.

Define $\pi_i^j(\varpi_c, \alpha_c, \beta_j)$ as the ith agent's expected payoff in the jth subgame where i =

f or h and j = S, N or C. Contest efficiency for the jth subgame given the homeowner's type is

then

$$\varepsilon_j(\varpi_h, \alpha_h, \beta_j) = \frac{\pi_f^j(\varpi_h, \alpha_h, \beta_j) + \pi_h^j(\varpi_h, \alpha_h, \beta_j)}{Max[V_f, V_h]}. \tag{19}$$

Substituting $\pi_f^j(\varpi_h, \alpha_h, \beta_j)$ and $\pi_h^j(\varpi_h, \alpha_h, \beta_j)$ for the alternative subgames equation (19)

can be rewritten generally as

$$\varepsilon_\lambda(\beta, \rho_\lambda, \varpi_\lambda, \alpha_\lambda) = \frac{(1 - \beta\rho_\lambda) + \beta\rho_\lambda(\varpi_\lambda - 1) + \beta^2\varpi_\lambda(\alpha_\lambda - 1)}{Max[\varpi_\lambda, 1]} \tag{20}$$

where functional arguments are suppressed, the subscript λ denotes the leader and β^2 denotes

the proportion of the leader's benefit that the leader dissipates in equilibrium. In the Citizen

suit subgame, the homeowner is the leader so λ = h and $\beta = \beta_C$. In the SLAPP subgame, the

firm is the leader so λ = f and $\beta = \beta_S$. Recall that while there is technically no leader in the

NASH subgame the solution to the NASH subgame can be written in the firm leader form.

Therefore, in the NASH subgame, λ = f and $\beta = \beta_N$.

Equation (20) highlights the effect of asymmetric benefits and abilities on contest

efficiency. The numerator of equation (20) represents absolute efficiency. The denominator

of equation (20) converts absolute efficiency to relative efficiency so that efficiency is

comparable across different types of homeowners. The first component of absolute efficiency,

$1 - \beta\rho_\lambda$, is the symmetric contest baseline and is always non-negative. When ϖ_λ = 1 and α_λ

= 1, ε_λ = 1 - R where R = 1/2. This is the traditional rent dissipated in a perfectly symmetric

contest with a ratio contest success function. The second and third expressions in the numerator, $\beta\rho_\lambda(\varpi_\lambda - 1)$ and $\beta^2\varpi_\lambda(\alpha_\lambda - 1)$, adjust the symmetric baseline for the effects of asymmetric benefits and abilities and are referred to as the benefit and ability effects.

Since the relative benefit impacts contest efficiency directly through its influence on the expected value and the maximum obtainable benefit of the contest and indirectly through its influence on the agents' equilibrium efforts, the benefit effect is a positive (negative) first-order effect as $\varpi_\lambda >(<) 1$. That is, baseline contest efficiency is increased when the leader's benefit is more than the follower's benefit. The magnitude of this increase or decrease depends on the absolute difference between benefits, and is magnified by the proportion of the leader's benefit that the leader dissipates in equilibrium and the leader's relative resolve. Note that since the impact of asymmetric benefits is a first order effect, the difference in agents' benefits is magnified by β instead of β^2 where $\beta > \beta^2$ since $\beta^2 \le 1$ for the leader to be willing to participate in this contest.

Since relative ability only impacts contest efficiency directly through its influence on the expected value of the contest and indirectly through its influence on the agents' equilibrium efforts, the ability effect is a positive (negative) second-order effect as $\alpha_\lambda >(<) 1$. That is, baseline efficiency is increased when the leader's ability exceeds the follower's ability. The magnitude of this increase or decrease in contest efficiency due to the ability effect depends on the absolute difference in abilities, and is magnified by the proportion of the leader's benefit that the leader dissipates in equilibrium and the leader's relative benefit.

Equation (20) suggest that efficiency is higher when the leader's benefit and ability

exceed the follower's benefit and ability. While this result may at first appear to contradict

Baik and Shogren's (1992) result that argues that it is efficient for underdogs to lead, this

contradiction can be resolved by noticing that the symmetric baseline is dependent on the

leader's equilibrium effort. When the favorite leads, β will be higher than when the underdog

leads. This implies that baseline efficiency will start off higher when the underdog leads. It

follows from Baik and Shogren (1992) that the high commitment of effort by a favorite when

the favorite leads in a complete information contest is never fully offset by the efficiency gains

due to the favorite having a higher benefit and/or ability.

Consider the difference in *ex post* efficiency between two general subgames that have

the same solution structure, $\varepsilon_\lambda(\beta,\rho_\lambda,\varpi_\lambda,\alpha_\lambda) - \varepsilon_\lambda(\beta',\rho_\lambda,\varpi_\lambda,\alpha_\lambda)$, where β^2 and β'^2 equal

the proportion of the leader's benefit that the leader dissipates in equilibrium for the two

alternative subgames under comparison. Simplifying,

$$\varepsilon_\lambda(\beta,\rho_\lambda,\varpi_\lambda,\alpha_\lambda) - \varepsilon_\lambda(\beta',\rho_\lambda,\varpi_\lambda,\alpha_\lambda) > (<)0 \text{ as}$$

$$(\beta-\beta')\left[-\rho_\lambda +\rho_\lambda(\varpi_\lambda - 1)+\varpi_\lambda(\beta+\beta')(\alpha_\lambda -1)\right] > (<)0. \tag{21}$$

$\beta - \beta'$, which is referred to as the effort effect, is positive (negative) as the leader's

equilibrium effort in the first subgame is greater (less) than the leader's equilibrium effort in

the alternative subgame. Define $\Psi_\lambda(\beta,\beta') = -\rho_\lambda +\rho_\lambda(\varpi_\lambda -1)+\varpi_\lambda(\beta+\beta')(\alpha_\lambda -1)$ to be

the net asymmetry effect. The first term in $\Psi_\lambda(\beta, \beta')$, $-\rho_\lambda$, accounts for the change in the

symmetric baseline due to a different equilibrium effort on the part of the leader in the

alternative subgame. The second and third terms, $\rho_\lambda(\varpi_\lambda - 1)$ and $\varpi_\lambda(\beta + \beta')(\alpha_\lambda - 1)$,

account for the change in the benefit and ability effects due to a different equilibrium effort on

the part of the leader in the alternative subgame.

Table 1 summarizes the sign of the asymmetry effect for a general comparison between

two subgames that can be written in the same leader form. Define the leader as benefit-strong

(weak) when $\varpi_\lambda >(<) 2$ and ability-strong (weak) when $\alpha_\lambda >(<) 1$. Also, define the leader to

be a strong favorite when $\rho_\lambda > 2$ and weak favorite $1 < \rho_\lambda \le 2$. The sign of the asymmetry

effect is unambiguously positive when the leader is both benefit-strong and ability-strong and

therefore, unambiguously a strong favorite. The sign of the asymmetry effect is

unambiguously negative when the leader is both benefit-weak and ability-weak. When the

leader is both benefit-weak and ability-weak, the leader is a weak favorite or underdog. The

sign of the asymmetry effect is ambiguous when the leader is benefit-strong and ability-weak,

or benefit-weak and ability-strong.

Given Table 1, net efficiency comparisons can be summarized by of effort and

Table 1: Sign of asymmetry effect for *ex post* efficiency comparisons between two subgames
with the same leader

	$\alpha_\lambda > 1$	$\alpha_\lambda = 1$	$\alpha_\lambda < 1$
$\varpi_\lambda > 2$	$\Psi_\lambda(\beta, \beta') > 0$	$\Psi_\lambda(\beta, \beta') > 0$	$\Psi_\lambda(\beta, \beta') >(<) 0^a$
$\varpi_\lambda = 2$	$\Psi_\lambda(\beta, \beta') > 0$	$\Psi_\lambda(\beta, \beta') = 0$	$\Psi_\lambda(\beta, \beta') < 0$
$\varpi_\lambda < 2$	$\Psi_\lambda(\beta, \beta') >(<) 0^a$	$\Psi_\lambda(\beta, \beta') < 0$	$\Psi_\lambda(\beta, \beta') < 0$

[a] As $\rho_\lambda(\varpi_\lambda - 2) + \varpi_\lambda(\beta + \beta')(\alpha_\lambda - 1) > (<)0$.

asymmetry effects. When the sign of the asymmetry effect is positive, efficiency in the

alternative subgame is higher (lower) if the effort effect is negative (positive). When the sign

of the asymmetry effect is negative, efficiency in the alternative subgame is higher (lower) if

the effort effect is positive (negative).

Since contest efficiency is derived for a contest of complete information, the concept

must be modified before it can be applied to a contest of incomplete information. Myerson

(1991) offers two alternative concepts when considering Pareto efficiency under uncertainty.

The first alternative is to consider *ex post* efficiency. The second alternative is to consider *ex

ante* efficiency.

Ex post Efficiency: An Analytic Perspective

Consider the difference in *ex post* efficiency in the SLAPP and SLAPP-free games for

a given homeowner's type. Let $\eta_k(v) = 1$ if the v type homeowner chooses Squawk and

$\eta_k(v) = 0$ if the v type homeowner chooses Sue when the kth subgame is played given the

homeowner chooses Squawk. For any given homeowner type, there are four possible ways

that eliminating the SLAPP action may effect the homeowner's timing decision. If $\eta_S = \eta_N =$

0, the homeowner always prefers Sue and plays the Citizen suit subgame regardless of

whether the SLAPP action is available. If $\eta_S = \eta_N = 1$, the homeowner always prefers

Squawk regardless of whether SLAPP action is available. If $\eta_S = 0$ and $\eta_N = 1$, the

homeowner prefers Sue in the SLAPP game and Squawk in the SLAPP-free game. If $\eta_S = 1$

and $\eta_N = 0$, the homeowner prefers Squawk in the SLAPP game and Sue in the SLAPP-free

game.

First, consider which game is more efficient when $\eta_S = \eta_N = 0$. In this case, the

Citizen suit subgame is played in both the SLAPP and SLAPP-free games. Therefore, $\lambda = C$,

$\beta = \beta_C$ and $\beta' = \beta_C$. Since $\beta = \beta'$, the effort effect is equal to 0 and equation (21) is equal to 0

regardless of asymmetry effect. Equilibrium behavior in the Citizen suit subgame is

independent of whether or not the SLAPP action is available. Therefore, the effort effect is 0

and *ex post* efficiency is the same in the SLAPP and SLAPP-free games.

Second, consider which game is more efficient when $\eta_S = \eta_N = 1$. In this case, the

SLAPP subgame is played in the SLAPP game and the NASH subgame is played in the

SLAPP-free game. $\beta = \beta_S$ and $\beta' = \beta_N$. Since the SLAPP and NASH subgames are both in

the firm leader form, efficiency can be compared directly using equation (21). However, it is

instructive to decompose this comparison into information and timing effects. $\varepsilon_S - \varepsilon_N = (\varepsilon_S -$

$\varepsilon_S') + (\varepsilon_S' - \varepsilon_N') + (\varepsilon_N' - \varepsilon_N)$ where ε_S' and ε_N' are *ex post* efficiency in the complete

information SLAPP and NASH subgames. Using equation (21),

$$
\varepsilon_S - \varepsilon_N = \left(\beta_S - \beta_S'\right)\Psi_f\left(\beta_S, \beta_S'\right)
$$
$$
+ \left(\beta_S' - \beta_N'\right)\Psi_f\left(\beta_S', \beta_N'\right) + \left(\beta_N' - \beta_N\right)\Psi_f\left(\beta_N', \beta_N\right). \tag{22}
$$

The first term on the right-hand side of equation (22) is an information effect from the SLAPP

game. The effort effect within this information effect is positive (negative) as

$E_{\Phi_S}\left(\rho_f(v)\right) > (<)\rho_f$ or as the firm's expected relative resolve in the SLAPP game is greater

(less) than the firm's actual relative resolve. The second term on the right-hand side of

equation (22) is a timing effect. The effort effect within this timing effect is positive

(negative) as $\rho_f > (<)1$ or as the firm is a complete information favorite (underdog). The

third term on the right-hand side of equation (22) is an information effect from the SLAPP-free game. The effort effect within this information effect is positive (negative) when the firm's equilibrium effort in the complete information NASH subgame is greater (less) than the firm's equilibrium effort in the incomplete information NASH subgame. When the firm is benefit-strong and ability-strong, the asymmetry effects are all positive. When the firm is benefit-weak and ability-weak, the asymmetry effects are all negative. Otherwise, the asymmetry effects are ambiguous.

Third, consider which game is more efficient when $\eta_S = 0$ and $\eta_N = 1$. In this case, the Citizen suit subgame is played in the SLAPP game and the NASH subgame is played in the SLAPP-free game. $\beta = \beta_C$ and $\beta' = \beta_N$. Since the solution to the Citizen suit subgame is in the homeowner leader form and the solution to the NASH subgame is in the firm leader form, a direct comparison using equation (21) is not possible. However, since the complete information NASH subgame can be written in either form, the comparison can be decomposed into timing and information effects which allow the application of equation (21), $\varepsilon_C - \varepsilon_N = (\varepsilon_C - \varepsilon_N') + (\varepsilon_N' - \varepsilon_N)$. Using equation (21),

$$\varepsilon_C - \varepsilon_N = (\beta_C - \beta_N')\Psi_h(\beta_C, \beta_N') + (\beta_N' - \beta_N)\Psi_f(\beta_N', \beta_N). \tag{23}$$

The first term on the right-hand side of equation (23) is a timing effect that is positive (negative) as $\rho_h > (<)1$ or as the homeowner is a complete information favorite (underdog). The second term on the right-hand side of equation (23) is an information effect from the SLAPP game similar to the information effect in equation (22). When the homeowner is benefit-strong and ability-strong, the homeowner's asymmetry effect is positive, while the

firm's asymmetry effect is negative. When the firm is benefit-strong and ability-strong, the firm's asymmetry effect is positive, while the homeowner's asymmetry effect is negative. Otherwise, the asymmetry effects are ambiguous.

Finally, consider which game is more efficient when $\eta_S = 1$ and $\eta_N = 0$. In this case, the SLAPP subgame is played in the SLAPP game and the Citizen suit subgame is played in the SLAPP-free game. $\beta = \beta_S$ and $\beta' = \beta_C$. As before, the solutions to the two subgames are not immediately comparable given equation (21). Therefore, the difference in efficiency is decomposed using timing and information effects. Since $\varepsilon_S - \varepsilon_C = (\varepsilon_S - \varepsilon_S') + (\varepsilon_S' - \varepsilon_N') + (\varepsilon_N' - \varepsilon_C)$, equation (21) implies,

$$
\begin{aligned}
\varepsilon_S - \varepsilon_N = &\left(\beta_S - \beta_S'\right)\Psi_f\left(\beta_S,\beta_S'\right) \\
&+\left(\beta_S'-\beta_N'\right)\Psi_f\left(\beta_S',\beta_N'\right)+\left(\beta_N'-\beta_C\right)\Psi_h\left(\beta_N',\beta_C\right)
\end{aligned} \tag{24}
$$

The first term on the right-hand side of equation (24) is an information effect from the SLAPP game similar to the first information effect in equation (22). The second term on the right-hand side of equation (24) is a timing effect similar to the timing effect in equation (22). The third term on the right-hand side of equation (22) is a timing effect similar to the timing effect in equation (23). The effort effects in the second and third terms have the same sign. As before, when the homeowner is benefit-strong and ability-strong, the homeowner's asymmetry effect is positive, while the firm's asymmetry effects are negative for both the timing and information effects. When the firm is benefit-strong and ability-strong, the firm's asymmetry effects are positive for both the timing and information effects, while the homeowner's asymmetry effect is negative.

Ex ante Efficiency: An Analytic Perspective

When the kth subgame is played given the homeowner chooses Squawk, *ex ante* contest efficiency is

$$E_k = \int_{v \in R} \left\{ (1 - \eta_k(v)) \varepsilon_C(v) + \eta_k(v) \varepsilon_k(v) \right\} dG(v, \tau). \tag{25}$$

Comparing *ex ante* efficiency in the SLAPP game to *ex ante* efficiency in the SLAPP-free game yields

$$E_S - E_N = \int_{v \in R} \left\{ (\eta_N(v) - \eta_S(v)) \varepsilon_C(v) + \eta_S(v) \varepsilon_S(v) - \eta_N(v) \varepsilon_N(v) \right\} dG(v, \tau). \tag{26}$$

There are three possibilities depending on the firm's updated beliefs in the two alternative games.

First, if $\beta_S = \beta_N$, the firm's equilibrium effort in the SLAPP subgame equals the firm's equilibrium effort in the NASH subgame. Proposition 9 implies that the set of homeowner's types that choose Squawk in the SLAPP game equals the set of homeowner's types that choose Squawk in the SLAPP-free game. Since homeowners' types with benefits less than 0 will not enter this contest and since *ex post* contest efficiency is the same for the SLAPP and SLAPP-free games when homeowner's types choose $\eta_S = \eta_N = 0$,

$$E_S - E_N = \int_{\check{v}_N}^{\hat{v}_N} (\varepsilon_S - \varepsilon_N) dG(v, \tau). \tag{27}$$

Given $\beta_S = \beta_N$, $\varepsilon_S - \varepsilon_N = 0$ for all v such that $\check{v}_N \le v \le \hat{v}_N$. Therefore, $E_S - E_N = 0$ and the SLAPP and SLAPP-free games are equally efficient. Since the firm's equilibrium effort in the SLAPP subgame is equal to the firm's equilibrium effort in the NASH subgame and since the

homeowner's best response function is independent of the subgame, equilibrium behavior and efficiency is the same regardless of whether the SLAPP or SLAPP-free game is played.

Second, if $\beta_S > \beta_N$, the firm's equilibrium effort in the SLAPP subgame is greater than the firm's equilibrium effort in the NASH subgame. Proposition 9 implies that the set of homeowner's types that choose Squawk in the SLAPP-free game contains the set of homeowner's types that choose Squawk in the SLAPP game such that

$$E_S - E_N = \int_{\tilde{v}_N}^{\tilde{v}_S} \left(\varepsilon_C - \varepsilon_N \right) dG(v,\tau) + \int_{\tilde{v}_S}^{\tilde{v}_S} \left(\varepsilon_S - \varepsilon_N \right) dG(v,\tau) + \int_{\tilde{v}_S}^{\tilde{v}_N} \left(\varepsilon_C - \varepsilon_N \right) dG(v,\tau). \quad (28)$$

In this instance, the elimination of the SLAPP action causes a set of homeowners' types to change their equilibrium timing decisions from Squawk to Sue. The net effect of this change in timing decisions on efficiency is captured by the first and third integrals on the right-hand side of equation (28). The proof of claim 4 in Appendix A and equation (23) imply that the timing effect is negative for the first integral and positive for the third integral in equation (28). The second integral on the right-hand side of equation (28) captures the difference in efficiency due to homeowner's types that choose Squawk regardless of whether the SLAPP action is available. $\beta_S > \beta_N$ implies that for a given homeowner's type within the second integral the net effort effect from equation (22) is positive. Given $G(v, \tau)$ and α_h, the remaining ambiguous *ex post* efficiency effects for a given homeowner's type can be evaluated. Integrating, over the relevant homeowners' types in equation (28) yields the difference in *ex ante* efficiency between the SLAPP and SLAPP-free games. When this difference is negative, eliminating SLAPPs decreases the *ex ante* efficiency of the game.

Third, if $\beta_S < \beta_N$, the firm's equilibrium effort in the SLAPP subgame is less than the firm's equilibrium effort in the NASH subgame. Proposition 9 implies that the set of homeowner's types that choose Squawk in the SLAPP game contains the set of homeowner's types that choose Squawk in the SLAPP-free game such that

$$E_S - E_N = \int_{\hat{v}_S}^{\hat{v}_N}(\varepsilon_S - \varepsilon_C)dG(v,\tau) + \int_{\hat{v}_N}^{\hat{v}_N}(\varepsilon_S - \varepsilon_N)dG(v,\tau) + \int_{\hat{v}_N}^{\hat{v}_S}(\varepsilon_S - \varepsilon_C)dG(v,\tau). \quad (29)$$

The first and third integrals in equation (29) capture the efficiency consequences of homeowner's types that change their equilibrium timing decision from Sue to Squawk when the SLAPP action is eliminated. The proof of claim 4 and equation (23) imply that the timing effect is positive for the first integral and negative for the third integral in equation (29). The second integral on the right-hand side equation (29) captures the difference in efficiency due to homeowners' types that choose Squawk regardless of whether the SLAPP action is available. $\beta_N > \beta_S$ implies that for a given homeowner's type within the second integral the net effort effect from equation (22) is negative. Given G(v, τ) and α_h, the remaining ambiguous *ex post* efficiency effects for a given homeowner's type can be evaluated. Integrating, over the relevant homeowners' types in equation (29) yields the difference in *ex ante* efficiency between the SLAPP and SLAPP-free games. When this difference is negative, eliminating SLAPPs decreases the *ex ante* efficiency of the game.

Except for the special case where $\beta_S = \beta_N$, the *ex post* and *ex ante* efficiency consequences of eliminating SLAPPs are ambiguous because of the interaction of timing, information and asymmetry effects. While the sign of the timing and asymmetry effects are generally determined by the actual relationship between the firm's and homeowner's benefits

and abilities, the sign of the information effects are generally determined by the *ex post*

accuracy of the firm's beliefs.

Ex ante Efficiency Comparisons Under Alternative Parameterizations

Given the general ambiguity of the analytic contest efficiency comparisons when $\beta_S >$

β_N or $\beta_S < \beta_N$ and the possible existence of multiple equilibria, the model is parameterized to

gain a better understanding of whether or not multiple equilibria do exist and which game is

more efficient. Since policy makers must make decisions *ex ante*, the analysis is confined to

ex ante contest efficiency. The parameterizations discussed assume that the firm's *a priori*

beliefs are normally distributed.[31] Under this assumption, three primary results emerge. First,

multiple equilibria may exist in the SLAPP game. When multiple equilibria do exist in the

SLAPP game, these equilibria include a unique pooling equilibrium where all homeowners'

types Sue, and a unique partially separating equilibrium. When the equilibrium is unique in the

SLAPP game, the equilibrium is a pooling equilibrium where all homeowners' types Sue.

Second, the perfect Bayesian equilibrium in the SLAPP-free game is a unique pooling

equilibrium where all homeowners' types Sue. Third, *ex ante* contest efficiency is

unambiguously higher in the SLAPP game when a partially separating equilibrium exists and is

played. Otherwise, contest efficiency is identical in the SLAPP and SLAPP-free games.

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[31] Initially, the simplest possible form of the firm's *a priori* beliefs, the uniform distribution, was considered. However, since $\beta_N(\varpi_c, \alpha_c, \tau) \leq \frac{1}{2}$ and $\beta_S(\varpi_c, \alpha_c, \tau) \leq \frac{1}{2}$ does not exist for any α_c in the range considered between 0.5 and 2, proposition 8 implies that all homeowner's types choose Sue and that $\eta_S(v) = \eta_N(v) = 0$. (26) then immediately implies that $E_S - E_N = 0$ and that the SLAPP game is always at least as efficient as the SLAPP-free game.

Given the firm's *a priori* beliefs are normally distributed, the parameterizations allow the homeowner's ability to vary between 0.5 and 2, the mean of the firm's *a priori* beliefs to vary between 0.05 and 2.5, and the variance of the firm's *a priori* beliefs to vary between 0.01 and 1.0. Figure 7, where the homeowner's ability is set to 1.2 and the variance of the firm's *a priori* beliefs is set to 0.01, captures the general pattern of the *ex ante* contest efficiency results.

In Figure 7, efficiency is plotted as a function of the mean of the firm's *a priori* beliefs. "Baseline" corresponds to efficiency in the SLAPP game assuming information is complete. In this instance, the unique equilibrium is for underdog homeowners' types to choose Sue and for favorite homeowners' types to choose Squawk. "Separating" corresponds to efficiency in the SLAPP game assuming information is incomplete and that the partially separating equilibrium is played when multiple equilibria exist. "Pooling" corresponds to efficiency in the SLAPP-free game and efficiency in the SLAPP game assuming information is incomplete and that the pooling equilibrium is played in the SLAPP game when multiple equilibria exist.

In general, as the mean of the firm's beliefs increases from 0 to 2.5, efficiency declines, but then begins to increase. "Pooling" efficiency converges to "Baseline" efficiency from below, and "Separating" efficiency converges to "Pooling" efficiency from above as the firm's mean belief becomes relatively small or relatively large. In some instances, "Separating" efficiency may actually exceed "Baseline" efficiency as the benefit of a general decrease in effort due to the firm's uncertainty outweighs the cost of inefficient timing decisions. This implies that the contest is more efficient with incomplete information than with complete information.
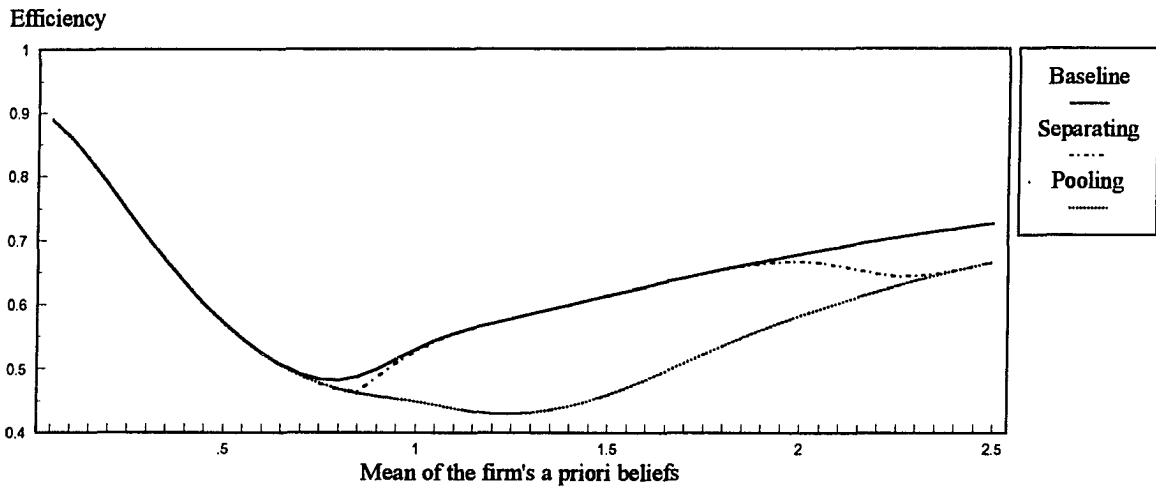
Efficiency

Figure 7: *Ex ante* efficiency when the homeowner's ability equals 1.2 and the variance of the firm's *a priori* beliefs equals 0.01

When the equilibrium in the SLAPP model is unique, "Separating" efficiency is equal to "Pooling" efficiency. Therefore, when the firm's mean belief is relatively high or relatively low, eliminating SLAPPs does not affect efficiency. However, when the firm's mean belief is more central, a separating equilibrium exists in the SLAPP game. For instance, when the mean of the firm's beliefs is between about 0.85 and 2.4 in Figure 7. This separating equilibrium is more efficient than the pooling equilibrium in the SLAPP and SLAPP-free games. Therefore, eliminating SLAPPs may decrease efficiency.

This general pattern is consistent across the large set of parameterizations that were considered. Figures 8 and 9 provide general comparisons that highlight the consistency of this pattern, and the effect of increasing the variance of the firm's beliefs while holding the

homeowner's ability constant and of increasing the ability of the homeowner while holding the variance of the firm's beliefs constant.

Figure 8, summarizes the general implications of an increase in the variance of a low-ability firm's *a priori* beliefs. In Figure 8, $\alpha_h = 1.2$, and Low, Medium and High variance correspond to 0.01, 0.0625 and 0.25. First, note that the range of efficiency decreases as the variance increases. Second, as the mean increases, "Separating" efficiency diverges from and converges back to "Pooling" efficiency sooner as the variance decreases. Third, "Pooling" efficiency converges closer to "Baseline" efficiency as the variance decreases.

Figure 9, summarizes the general implication of an increase in the homeowner's ability while holding the variance of the firm's *a priori* beliefs constant at the lowest parameterization, 0.01. In Figure 9, the variance of the firm's beliefs is equal to 0.01, and Low, Medium and High ability correspond to α_h equal to 0.8, 1.0 and 1.2. First, note that efficiency tends to be higher when the firm's mean belief is relatively low and the homeowner's ability is low. When the firm's mean belief is relatively high, efficiency tends to be higher as the homeowner's ability is high. Second, as the mean increases, "Separating" efficiency diverges from and converges back to "Pooling" efficiency sooner as the homeowner's ability increases. Third, as the mean increases, changes in ability seem to have little effect on how close "Pooling" efficiency converges to "Baseline" efficiency.

In summary, the SLAPP game is always at least as efficient as the SLAPP-free game such that eliminating SLAPPs may reduce efficiency. The existence of a separating equilibrium is sensitive to both the homeowner's ability and the variance of the firm's beliefs.

(a)

(b)

(c)
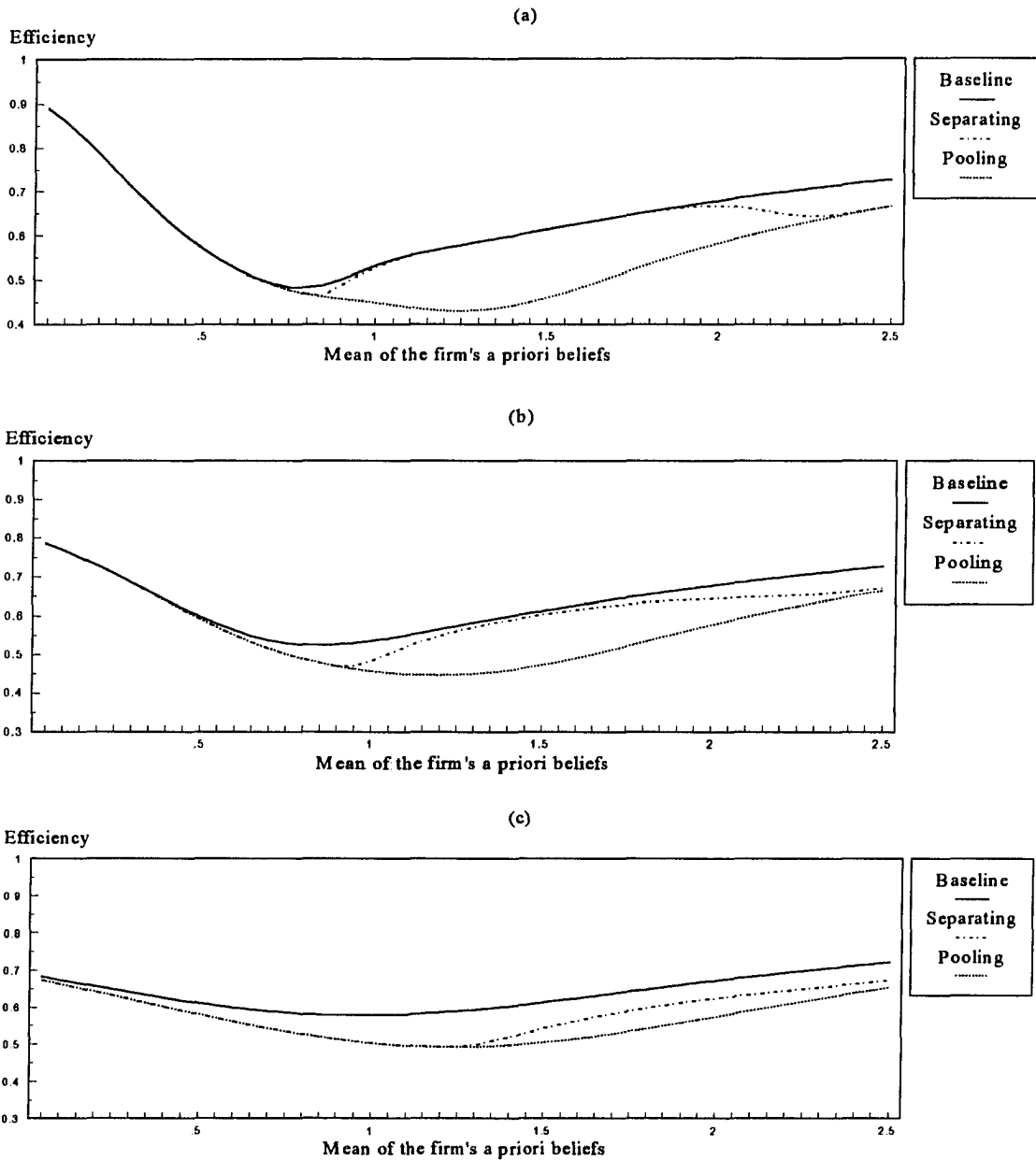
Figure 8: (a) *Ex ante* efficiency for high ability homeowners and a low variance in
the firm's *a priori* beliefs

(b) *Ex ante* efficiency for high ability homeowners and a medium variance in
the firm's *a priori* beliefs

(c) *Ex ante* efficiency for high ability homeowners and a high variance in
the firm's *a priori* beliefs

(a)

Efficiency

(b)

Efficiency

(c)
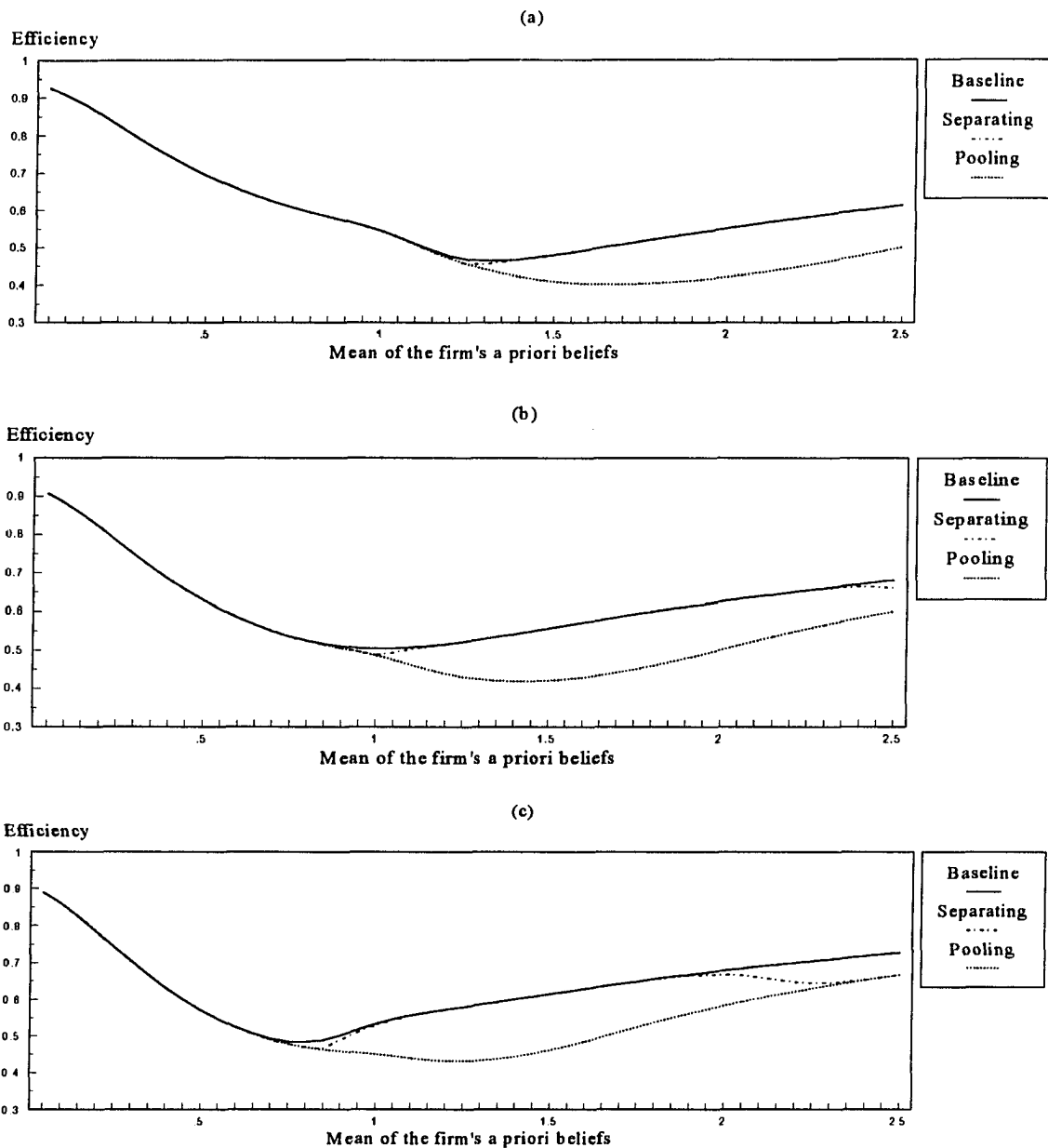
Efficiency

Figure 9: (a) *Ex ante* efficiency for low ability homeowners and a low variance in the firm's a priori beliefs

(b) *Ex ante* efficiency for medium ability homeowners and a low variance in the firm's *a priori* beliefs

(c) *Ex ante* efficiency for high ability homeowners and a low variance in the firm's *a priori* beliefs

All types of efficiency ("Baseline," Separating" and "Pooling") tend to be higher when the firm's mean belief tends to be low, and the homeowner's ability tends to be low. All types of efficiency tend to be higher when the firm's mean belief tends to be high, and the homeowner's ability tends to be high. All types of efficiency also tend to be higher when the firm's mean belief is relatively high or relatively low and the variance of the firm's beliefs is low, and when the firm's mean belief is more central and the variance of the firm's beliefs is high. The degree to which "Pooling" efficiency converges to "Baseline" efficiency is generally insensitive to the homeowner's ability, but quite sensitive to the variance of the firm's beliefs.

AN EXPERIMENTAL TEST OF THE PERFECT BAYESIAN EQUILIBRIUM AND THE INTUITIVE REFINEMENT

The perfect Bayesian equilibrium concept offers strong predictions regarding an

agent's equilibrium behavior in the SLAPP game. While the predicted equilibrium is unique

for many parameterizations, multiple equilibria exist for other parameterizations. These

equilibria include a unique unintuitive pooling equilibrium, and a unique intuitive separating

equilibrium. In an effort to choose which of these two equilibria is more likely, an experiment

is conducted with a two homeowner type SLAPP game. The results of the experiment

suggest two important conclusions. First, the statistical evidence supports non-random play in

the direction of both the intuitive and unintuitive equilibria, and differences in subject behavior

across sessions. Second, the results support Plott's (1995) discovered preference hypothesis

which suggest that subject behavior evolves through three stages of rationality. These results

suggest that future sessions providing subjects with additional time to progress through Plott's

three stages of rationality are likely to produce conclusive evidence to determine whether

equilibrium behavior is predicted by the intuitive or unintuitive equilibrium.[32]

The Experimental Game

Figure 10 presents the extensive form game.[33] The game consists of three types of risk

neutral players, an A1-type player, an A2-type player and a B-type player which are referred

---

[32] The time constraints involved in administering this experiment without the benefit of computers restricted the feasible number of rounds to 5 which did not provide all subjects with ample time to evolve through Plott's three stages of learning. Future experiments aided by computers would make additional rounds feasible and provide subjects with enough time to learn.

[33] The payoffs in the experimental game are the result of a transformation of the payoffs generated from the formal model. This transformation was conducted to improve saliency given the results from the session 0 pilot experiment and maintained the payoff rankings, the efficiency rankings, the games two equilibria and the critical switching probabilities defined below.
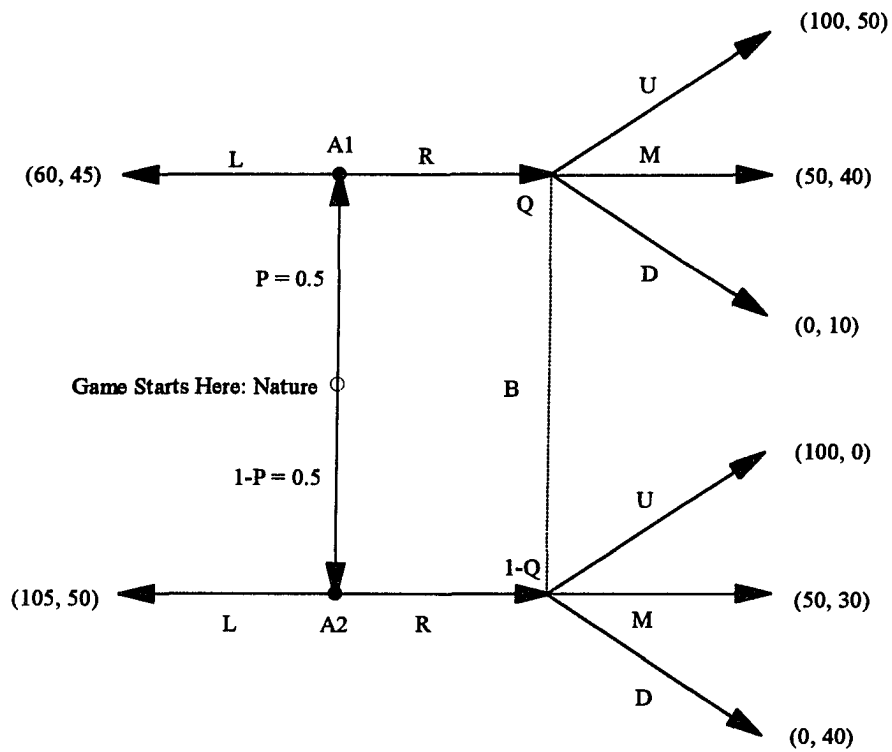
Figure 10: Single period experimental game

to as A1, A2 and B below. A1 represents the first type of homeowner, A2 represents the second type of homeowner and B represents the firm. The game starts by Nature randomly choosing whether B plays A1 or A2 with equal probability. Once Nature has selected B's opponent, the A1 or A2 player chooses between R or L (see Figure 10). The choice R corresponds to the homeowner choosing Squawk, while the choice L corresponds to the homeowner choosing Sue.

If A1 or A2 choose L, then the game ends. A1's payoff is 60, A2's payoff is 105 and B's payoff is 45 if he/she is playing A1 and 50 if he/she is playing A2. These payoffs are representative of the equilibrium payoffs in the Citizen's suit subgame.

If A1 or A2 choose R, then B must choose U, M or D not knowing whether he/she is playing A1 or A2. If B chooses U, A1's or A2's payoff is 100 and B's payoff is 50 if he/she is playing A1 and 0 if he/she is playing A2. If B chooses M, A1's or A2's payoff is 50 and B's payoff 40 if he/she is playing A1 and 30 if he/she is playing A2. If B chooses D, A1's or A2's payoff is 0 and B's payoff 10 if he/she is playing A1 and 40 if he/she is playing A2. These payoffs are representative of the equilibrium payoffs given the homeowner chooses Squawk, the firm chooses SLAPP and the firm has one of three updated beliefs. First, if A1 chooses R and A2 chooses L, then Bayes rule implies the firm's believes it is playing A1 given R is chosen. Second, if A1 chooses R and A2 chooses R, then Bayes rule implies the firm's believes it is playing A1 with probability 0.5 given R is chosen. Third, if A1 chooses L and A2 chooses R, then Bayes rule implies the firm's believes it is playing A2 given R is chosen.

Consider how these three players will play this single period game. Define P as B's initial belief that he/she is matched with A1 and Q as B's updated belief that he/she is matched with A1 given A1 or A2 choose R.

First, B chooses the action that maximizes his/her expected payoff given his/her updated beliefs. B's expected payoff from choosing U, M or D is $50Q + 0(1 - Q)$, $40Q + 30(1 - Q)$ or $10Q + 40(1 - Q)$, respectively. Comparing any of B's two alternative

actions given Q, B's decision is summarized by the function

$$B(Q) = \begin{cases} U, & \text{if } Q > 0.75 \\ U \text{ or } M, & \text{if } Q = 0.75 \\ M, & \text{if } 0.75 > Q > 0.25 \\ M \text{ or } D, & \text{if } Q = 0.25 \\ D, & \text{if } Q < 0.25 \end{cases}.$$

A1 chooses the action that maximizes his/her expected payoff where A1's expected

payoff from choosing R or L is $100 \Pr(U|Q) + 50 \Pr(M|Q) + 0 \Pr(D|Q)$ or 60, respectively.

A1's decision can be summarized by the function

$$A1(Q) = \begin{cases} L, & \text{if } Q < 0.75, \text{ or } Q = 0.75 \text{ and } \Pr(U|Q = 0.75) < 0.20 \\ R, & \text{if } Q > 0.75, \text{ or } Q = 0.75 \text{ and } \Pr(U|Q = 0.75) > 0.20 \text{ where} \\ L \text{ or } R, & \text{if } Q = 0.75 \text{ and } \Pr(U|Q = 0.75) = 0.20 \end{cases}$$

$\Pr(U|Q = 0.75)$ is determined by B(Q).

A2 chooses the action that maximizes his/her expected payoff where A2's expected

payoff from choosing R or L is $100 \Pr(U|Q) + 50 \Pr(M|Q) + 0 \Pr(D|Q)$ or 105, respectively.

Since 105 exceeds $100 \Pr(U|Q) + 50 \Pr(M|Q) + 0 \Pr(D|Q)$ for all Q such that $0 \le Q \le 1$, A2's

expected payoff is maximized by choosing L.

There are two perfect Bayesian equilibria for this game. The first is an unintuitive

pooling equilibrium where both A1 and A2 choose L. This represents an equilibrium provided

$Q < 0.75$ or $Q = 0.75$ and $\Pr(U|Q = 0.75) < 0.6 - 0.5 \Pr(M|Q = 0.75)$. However, this

equilibrium is unintuitive because while A1 stands to benefit from deviating from L if B

chooses U, A2 can never benefit from deviating from L. Therefore, if a deviation occurs, B

should believe that he/she is playing A1 with probability 1 and choose U. If this is the case,

then A1's best response is to play R and not L.[34] This is a perfect Bayesian equilibrium

because if Q < 0.75, then A1 and A2 best response is to choose L. While this belief seems

unreasonable, the perfect Bayesian equilibrium concept is not strong enough to eliminate this

belief.

The second equilibrium is an intuitive separating equilibrium such that A1 chooses R,

A2 chooses L and B chooses U given his/her opponent chooses R. Given these strategies,

Bayes rule implies Q = 1. If Q = 1, then B's best response is to choose U. If B chooses U

given either A1 or A2 choose R, A1's best response is to choose R and A2's best response is

to choose L thus supporting the firm's belief.[35]

Experimental Design and Hypotheses

The experiment was conducted in three sessions during April 1995. The first two

sessions, sessions 2 and 3, used identical incentive mechanisms, while the third session,

session 4, used a single elimination tournament as an alternative incentive mechanism as in

Baik and Shogren (1994b) and Shogren (1994).[36] Each session took approximately 2 hours.

A total of 64 subjects were recruited from microeconomics and macroeconomics principle

classes at Iowa State University. For the first two sessions, subjects were told that they

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[34] For an excellent concise explanation of intuitive versus unintuitive equilibria see Banks, Camerer and Porter (1994).

[35] Recall that these solutions are derived under the assumption of risk neutrality. Relaxing the assumption of risk neutrality does not change the intuitive equilibrium of the game. However the unintuitive equilibrium may be slightly different where this difference will affect the critical values in the B's and A1's decision functions. If preferences are risk averse, the unintuitive equilibrium is more likely given an unintuitive belief. If preferences are risk loving, the unintuitive equilibrium is less likely given an unintuitive belief.

[36] Sessions 0 and 1 were pilot experiments that are referred to, but not reported.

would earn an average of about $30.00 with maximum possible earnings of up to $60.00. For the third session subjects were told that they would earn an average of about $30.00 with maximum possible earnings of up to $110.00.

General procedures

In the first two sessions, fifteen subjects were randomly assigned to one of the three types such that there were five players of each type. In the third session, twenty-four subjects were randomly assigned to one of the three types such that there were eight players of each type. In all three sessions, each subject was issued a folder which contained a consent form, instructions, a quiz, a sheet with two figures, an Example Round Strategy Sheet that was type specific, an Example Round Earnings Sheet that was type specific and a Practice Round Strategy Sheet that was type specific.[37]

After the consent form was read and signed by all participants, the instructions were read out loud by the monitor to create a common pool of information. During the reading, the sheet with the two figures was shown on an overhead and referred to such that the participants would understand how to use the diagrams to determine their payoffs. This extensive form representation was used given Schotter, Weigelt and Wilson's (1994) evidence that strategic threats are more common in games presented in the normal form as opposed to the extensive form. Once the instructions were finished subjects completed the quiz.

After reviewing the quiz, subjects were asked to complete their Practice Round Strategy Sheet and wait for the results to be determined. The results of the practice round

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[37] Examples of these materials, except for the consent form, are supplied in Appendix C.

were returned on the subject's Practice Round Earnings Sheet along with a new Strategy

Sheet. The subjects were asked to review the Practice Round Earnings Sheet, to complete

their new Strategy Sheet and to wait for the results to be determined. This process continued

for the four binding rounds.

A round consisted of five games in the first two sessions and four games in the third

session. These games were played simultaneously such that subjects did not receive feedback

regarding the results of these games until the end of the round. This was accomplished by

having subjects complete a Strategy Sheet. The Strategy Sheet consisted of two parts. Part I

elicited how the subject believed other subjects would choose to play the games by having the

subjects respond to four statements. For sessions 2 and 3, all subjects circled their best

guesses to the following:

(i)   I think the (randomly selected) A1s will choose R in [0   1   2   3   4   5] of the

        five games.

(ii)   I think the (randomly selected) A2s will choose R in [0   1   2   3   4   5] of the

        five games.

(iii)   I think the (randomly selected) Bs will choose U in [0   1   2   3   4   5] of the five

        games.

(iv)   I think the (randomly selected) Bs will choose M in [0   1   2   3   4   5] of the

        five games. **Note that the sum of your responses in statements 3 and 4 should not**

        exceed 5.[38, 39]

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[38] Examples for session 4 are in Appendix C.
[39] The choice of the randomly selected subjects of each type is explained below.

Part II asked the subject to choose how to play each of the games in the round. For sessions

2 and 3, the A1s and A2s circled one choice for each of the following:

1) For **Game 1**, I choose   R.   L.

2) For **Game 2**, I choose   R.   L.

3) For **Game 3**, I choose   R.   L.

4) For **Game 4**, I choose   R.   L.

5) For **Game 5**, I choose   R.   L. [40]

A subject's round earnings (denominated in tokens) equaled the sum of the subject's payoffs

for all of the games in that round. Between rounds each subject received a Round Earnings

Sheet that provided him/her with feedback on his/her resulting payoffs and the play of

randomly selected subjects of each type.[41]

Specific methodological considerations

Risk preferences were controlled by two distinct methods. First, instead of

randomizing B's opponent, B played each game against an A1 and an A2. B's payoff for the

game was equal to the sum of his/her payoff from playing both A1 and A2. This method

eliminated any risk involved with a randomizing device, while maintaining a risk neutral

player's incentives. However, this method does not control for risk attitudes that are

associated with a subject's uncertainty regarding his/her opponent's choices. The second

method altered the payoffs by increasing cardinal differences while preserving ordinal

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[40] Examples for the Bs in all sessions and the A1 and A2 subjects in session 4 are in Appendix C.
[41] Examples for all subjects and all sessions are in Appendix C.

rankings. This method was used by Banks, Camerer and Porter (1994), and reduces the

likelihood that risk attitudes change a subject's equilibrium action.[42]

As mentioned above, the subject's Strategy Sheet asked the subject to report his/her

subjective beliefs regarding how they thought other subjects would choose to play the game. This

accomplishes two important goals. First, this method provides additional information to determine

whether or not a subject has risk neutral, risk loving or risk averse preferences. Second, this

method provides information on a subject's belief formation and whether or not a subject uses this

information to determine his/her appropriate action. The elicitation of such beliefs was suggested

by Banks, Camerer and Porter (1994). To encourage the thoughtful revelation of these beliefs,

incentive mechanisms were employed. For instance, subjects were paid $0.25 for each correct

prediction in sessions 2 and 3, while the number of correct predictions was used as a tie breaker to

determine advancement in the tournament in session 4.

To maintain the one-shot game incentives and to reduce the development of

cooperative play over repeated trials, subjects were randomly matched with a different player

for each game within a round and between rounds. For the first two sessions, each of the five

players of a given type were randomly ordered. This order was then used to determine which

player's strategy would be played for each of the five games. Therefore, each round a subject

received an equally weighted random sample of how his/her five opponents chose to play the

game.

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[42] Initially, the method set forth by Berg, Daley, Dickhaut and O'Brien (1986) was also employed. However, since
this method added an additional layer of complexity to the experiment and debriefings with subjects in the session 0
pilot experiment indicated that the method had failed to accomplish its objective, this method was eliminated from
the experiments reported here in favor of the transformed payoffs.

In session 4, given the use of the single elimination tournament, the subject matching was more complicated. For the practice round and the first round of the tournament, the eight subjects of a given type were randomly ordered and assigned to one of the four games in each of these two rounds. This implied that after the first two rounds subjects had an equally weighted random sample of how his/her eight opponents chose to play the game. After the first round of the tournament, four subjects of each type were eliminated from the experiment. The strategies of the four remaining subjects of each type were randomly assigned to one of the round two games. After the second round of the tournament, two subjects of each type were eliminated from the experiment. The strategies for the remaining two subjects of each type were randomly assigned to two of the round three games. After the third round of the tournament, one subject of each type was eliminated from the experiment. The strategies of the remaining three subjects (one of each type) were played for each of the four round four games.[43]

The final methodological consideration controlled the history of the game reported to individual subjects. In an effort to expedite learning and to maintain a common pool of information across different types of subjects, the strategies played by the randomly selected players of each type were reported to all subjects on their Round Earnings Sheet. That is, the number of randomly selected A1s that chose R, the number of randomly selected A2s that chose R, the number of randomly selected Bs that chose U, and the number of randomly

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[43] Note that if these matching procedures are not sufficient to guarantee that all cooperation is eliminated from one round to the next, any collusion is expected to encourage the play of the intuitive equilibrium since the intuitive equilibrium is the result of a Pareto dominant set of actions.

selected Bs that chose M were reported to each subject at the end of each round. This provided all subjects with a common history.

Incentive mechanisms

In sessions 2 and 3, subjects were paid a $10.00 participation fee in addition to $0.01 for each token they earned in the final four rounds. The average earnings in the first and second sessions were $28.26 and $28.30 with standard deviations of $3.11 and $4.04, and ranges of $23.05 to $33.00 and $22.40 to $33.00.

After sessions 2 and 3, it became apparent that the incentive mechanism encouraged learning, but it was rather passive and slow. In order to encourage faster more active learning, session 4 was conducted with an alternative incentive mechanism. In session 4, subjects competed in a single elimination tournament. For the tournament, subjects were paid a $5.00 participation fee plus the value of their tokens in the round that they were eliminated. If a subject was eliminated in the first, second, or third round of the tournament, he/she earned $0.01, $0.05 or $0.10 for each token earned in that round. If the subject made it to the fourth round, he/she earned $0.25 for each token earned in the fourth round. Subjects advanced in the tournament by earning more tokens in the round than a randomly selected subject of their same type. In the event of a tie, the accuracy of a subject's beliefs about the randomly selected opponents' actions in the current round was used as a first tie breaker. In the event that two subjects had equally accurate beliefs, a coin toss was used as second tie breaker. On average, subjects earned $27.25 with a standard deviation of $30.53 and a range of $7.10 to $110.00.

Hypotheses

The hypotheses tested concern equilibrium behavior and differences in behavior across sessions, rounds and incentive mechanisms. First, the null hypothesis that subjects play the intuitive equilibrium, the unintuitive equilibrium or purely random is tested. Second, the null hypothesis that subject behavior does not differ by round or session in sessions 2 and 3 is tested. Third, the null hypothesis that subject behavior differs only by session in sessions 2 and 3 is tested. Fourth, the null hypothesis that subject behavior differs only by round in session 2 and 3 is tested. Fifth, the null hypothesis that subject behavior in rounds 1 and 2 of session 2 and 3 differs from rounds 1 and 2 of session 4.[44]

Results

This section reports the results of the three experimental sessions. First, the data is described by round, session and subject type placing particular emphasis on equilibrium behavior and experimental efficiency. The data is then aggregated by subject type and described by round and session also emphasizing equilibrium behavior and experimental efficiency. Next, nonparametric statistical tests of equilibrium behavior and differences across rounds, sessions and incentive mechanisms are discussed and performed.

Subject play by type, round and session

Recall that in each round the A1s chose R or L for five games in sessions 2 and 3, and for four games in session 4. Table 2 reports the number of A1s that chose a particular

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[44] Rounds 1 and 2 are the only rounds considered for these comparisons because after round 2 some subjects are eliminated from the session 4 experiment. Therefore, in the final three rounds of the session 4 tournament, the subject pool is no longer a random sample.

Table 2: The A1 subjects' strategies by session and round

Session	Choose R[a]	Round 1[b]	Round 2	Round 3	Round 4	Round 5
2	0.00	1	1	1	0	0
	0.20	1	0	0	1	1
	0.40	0	2	2	1	2
	0.60	2	1	2	3	0
	0.80	1	1	0	0	1
	1.00	0	0	0	0	1
3	0.00	0	0	1	0	0
	0.20	0	0	1	1	2
	0.40	2	3	1	0	1
	0.60	3	2	1	1	2
	0.80	0	0	0	1	0
	1.00	0	0	1	2	0
4	0.25	1	2	1	1	0
	0.50	6	5	1	1	0
	0.75	1	1	2	0	1

[a] Choose R is the probability that an A1 chose R in any given round.

[b] Round 1 through Round 5 is the number of A1s that chose R for a given probability in each round.

strategy defined in terms of the probability that R was chosen. If an A1 was playing a purely intuitive strategy, then the probability that the subject chose R was 1.0. If an A1 was playing a purely unintuitive strategy, then the probability that the A1 chose R was 0. On average, 11.0% of the A1s chose a purely intuitive or a purely unintuitive strategy in each round for sessions 2, 3 and 4. In session 2, pure strategy play was evenly dispersed across rounds 1, 2, 3 and 5 with 75.0% of pure strategy play being unintuitive. In session 3, pure strategy play occurred exclusively in rounds 3 and 4 with 75.0% of pure strategy play being intuitive. In session 4, no pure strategy was chosen in any round. On average, 60.3% of the A1s in sessions 2, 3 and 4 chose R with a probability between 0.40 and 0.60.

In each round, the A2s also chose to play either R or L for five games in sessions 2 and 3 and for four games in session 4. Table 3 reports the number of A2s that chose a particular strategy defined in terms of the probability that R was chosen. If an A2 was playing a purely intuitive or unintuitive strategy, then the probability that the A2 chose R was 0. On average, 74.0% of the A2s in sessions 2, 3 and 4 chose to play a pure equilibrium strategy in each round. Also, the percentage of subjects that chose a pure equilibrium strategy is non-decreasing by round in all three sessions.

In each round, the Bs chose U, M or D for five games in sessions 2 and 3, and for four games in session 4. Table 4 reports the number of Bs that chose a particular strategy defined in terms of the probability that U was chosen and the probability that M was chosen. If a B was playing a purely intuitive strategy, then the probability that the B chose U was 1.0. Since a B did not get the opportunity to move when the unintuitive equilibrium was played, any pure

Table 3: The A2 subjects' strategies by session and round

Session	Choose R[a]	Round 1[b]	Round 2	Round 3	Round 4	Round 5
2	0.00	2	2	4	4	4
	0.20	1	1	0	0	0
	0.40	1	1	1	0	1
	0.60	0	1	0	1	0
	0.80	1	0	0	0	0
3	0.00	3	3	4	5	5
	0.20	0	1	0	0	0
	0.40	1	0	1	0	0
	0.60	0	1	0	0	0
	0.80	1	0	0	0	0
4	0.00	4	7	4	2	1
	0.25	2	1	0	0	0
	0.50	1	0	0	0	0
	1.00	1	0	0	0	0

[a] Choose R is the probability an A2 chose R in any given round.

[b] Round 1 through Round 5 is the number of A2s that chose R for the given probability in each round.

Table 4: The B subjects' strategies by session and round

Session	Choose U[a]	Choose M[b]	Round 1[c]	Round 2	Round 3	Round 4	Round 5
2	0.00	0.80	1	0	0	0	0
	0.00	1.00	1	1	1	2	1
	0.20	0.60	1	1	1	1	1
	0.40	0.20	0	1	0	0	0
	0.40	0.40	0	0	1	0	0
	0.80	0.20	0	1	0	0	0
	1.00	0.00	2	1	2	2	3
3	0.00	0.00	0	0	0	1	0
	0.00	0.60	0	0	1	0	0
	0.00	0.80	0	0	0	0	1
	0.00	1.00	2	2	2	3	2
	0.20	0.80	0	1	0	0	0
	0.40	0.20	1	0	0	0	0
	0.40	0.40	1	0	0	0	0
	0.60	0.20	0	0	1	0	0
	0.60	0.40	1	2	0	0	0
	0.80	0.00	0	0	0	0	1
	1.00	0.00	0	0	1	1	1
4	0.00	0.00	1	0	0	0	0
	0.00	0.25	1	1	0	0	0
	0.00	1.00	1	2	2	0	0
	0.25	0.50	1	3	1	0	0
	0.25	0.75	1	0	0	0	0
	0.50	0.00	0	0	0	1	0
	0.50	0.25	2	0	0	0	0
	0.50	0.50	1	0	0	0	0
	0.75	0.00	0	1	0	0	0
	1.00	0.00	0	1	1	1	1

[a] Choose U is the probability that a B subject chose U in any given round.

[b] Choose M is the probability that a B subject chose M in any given round.

[c] Round 1 through Round 5 is the number of Bs that chose U and M for the given probabilities in each round.

strategy represented a purely unintuitive equilibrium strategy. Therefore, in Table 4, pure unintuitive equilibrium strategies are denoted by Choose U = 0 and Choose M = 0, Choose U = 0 and Choose M = 1.0, and Choose U = 1.0 and Choose M = 0. On average, 56.2% of the Bs in sessions 2, 3 and 4 played a purely intuitive or a purely unintuitive strategy in each round. In session 2, 62.5% of pure strategy play was intuitive. In session 3, 20.0% of pure strategy play was intuitive. In session 4, 40.0% of pure strategy play was intuitive.

Pure strategy play was most common for the A2s and least common for the A1s. When the session 2 A1s chose a pure strategy, this strategy was usually unintuitive. When the session 3 A1s chose a pure strategy, this strategy was usually intuitive. However, the majority of A1s seemed to choose randomly between R and L with equal probability. Almost all A2s move quickly to their pure strategy equilibrium. With the exception of one subject in session 2, all subjects are playing in equilibrium after Round 3. The Bs are playing pure strategy equilibrium behavior with much greater frequency than the A1s. The Bs pure strategy play is much more intuitive in session 2 than it is in either sessions 3 or 4.

Figure 11 (a) plots the average probability that all of the A1s chose R by session and round. In session 2, the probability that the A1s chose R increased slightly by round with the exception of Round 3 where there was a slight decrease. In session 3, the probability that the A1s chose R decreased slightly by Round with the exception of Round 4 where there was a strong increase. In session 4, the probability that the A1s chose R did not consistently increase or decrease by round. In all three session, the marginal changes between rounds tended to increase in later rounds.
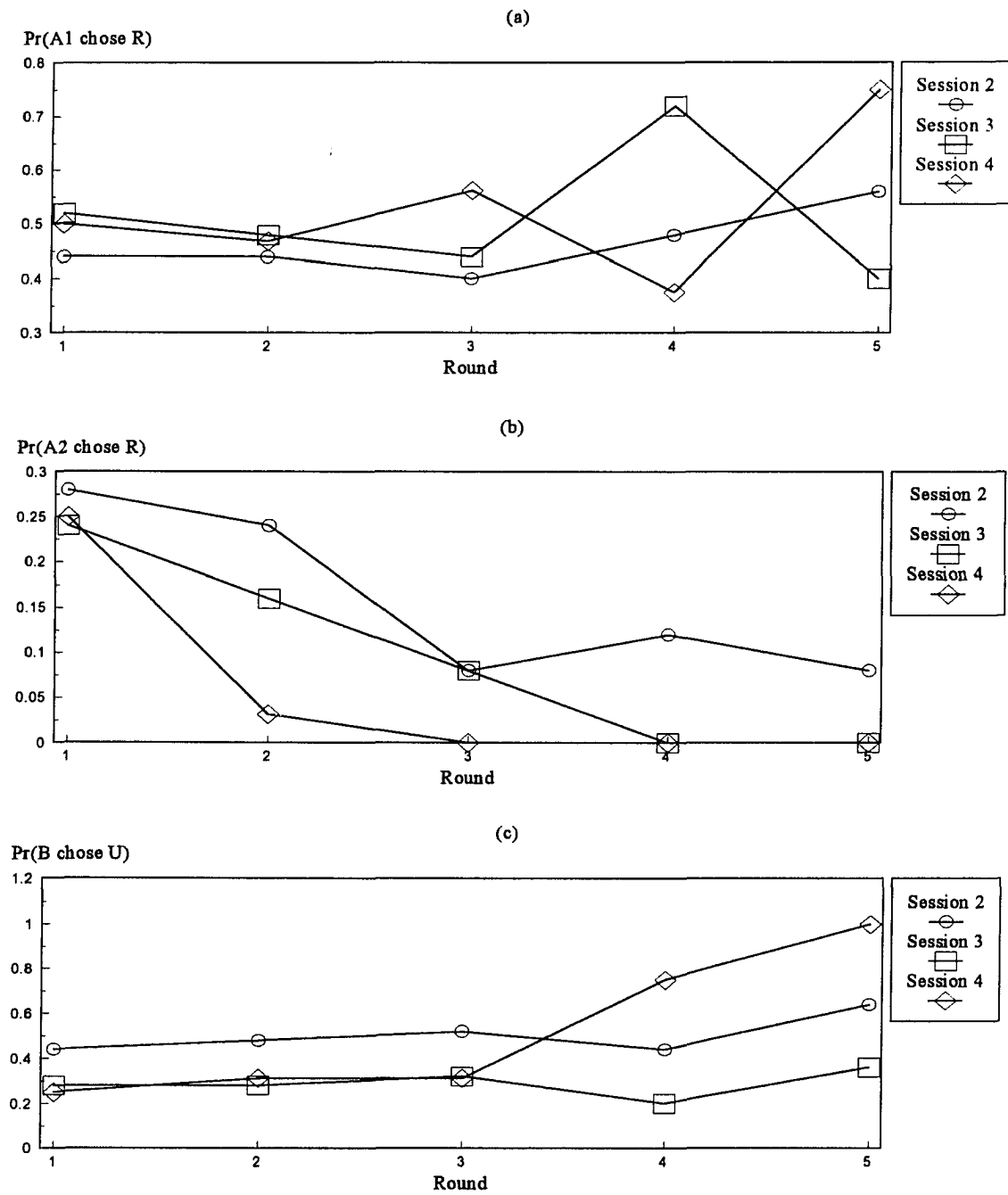
Figure 11: (a) The average probability that the A1s chose R by round and session
(b) The average probability that the A2s chose R by round and session
(c) The average probability that the Bs chose U by round and session

Figure 11 (b) plots the average probability that the A2s chose R by session and round. In all three sessions, the probability that the A2s chose R decreased with the exception of Round 4 in session 2 where there was a slight increase. In session 2, there was always some positive probability that the A2s chose R. In sessions 3 and 4, the probability that the A2s chose R falls to 0 by Round 4. This convergence to equilibrium play was more rapid in session 4 where by Round 2 the probability that the A2s chose R was less than 0.05 and by Round 3 was 0.

Figure 11 (c) plots the average probability that the Bs chose U by session and round. In sessions 2 and 3, the probability that the Bs chose U generally increased slightly by round with the exception of Round 4 where there was a modest decrease. In session 4, the probability that the Bs chose U was non-decreasing. There were strong increases in the probability that the Bs chose U in session 4 for Rounds 4 and 5.

Figure 12 shows the average efficiency of the subjects' choices by type, session and round. Efficiency is defined as the proportion of the maximum obtainable rewards captured by the subjects. In Figure 12 (a), "Intuitive" denotes efficiency for the A1s given all of the subjects play the intuitive equilibrium, while "Unintuitive" denotes efficiency for the A1s given all of the subjects play the unintuitive equilibrium. In Figure 12 (b), "(Un)Intuitive" denotes the efficiency for the A2s given all of the subjects play the intuitive equilibrium, or given all of the subjects play the unintuitive equilibrium. In Figure 12 (c), "Intuitive" denotes efficiency for the Bs given all of the subjects play the intuitive equilibrium, while "Unintuitive" denotes efficiency for the Bs given all of the subjects play the unintuitive equilibrium. For all three

subject types, the maximum obtainable reward occurs when all subject types play the intuitive equilibrium.

In Figure 12 (a), (b) and (c), there are three notable points. First, with a few exceptions, efficiency increased by round. Second, the A2s efficiency converged rapidly toward 1.0 and reaches 1.0 in sessions 3 and 4 by Round 4 which suggest the A2s. Third, while Table 2 and Figure 11 (a) suggest that the A1s' played randomly, the A1s efficiency was generally as high as if the A1s would have played purely unintuitive.

Subject play by round and session

The probability that the subjects played the intuitive equilibrium is equal to the probability that the A1s chose R, the A2s chose L and the Bs chose U. The probability that the subjects played the unintuitive equilibrium is equal to the probability that the A1s chose L and the A2s chose L. Figure 13 shows the dynamic time path of the probability that the subjects played the intuitive equilibrium and the unintuitive equilibrium. The point (0,1.0) represents intuitive play with probability 1.0. The point (1.0,0) represent unintuitive play with probability 1.0 and the origin represents non-Nash play with probability 1.0. These three points create a simplex where the solid star within the simplex denotes purely random play. That is, the probability of intuitive and unintuitive play assuming the A1s and A2s chose R with a probability equal to 1/2, and the Bs chose U and M with probabilities equal to 1/3. The solid dot shows the probability of intuitive and unintuitive play for round 1, session 2 This solid dot is followed by a sequence of open dots denoting the probability of intuitive and unintuitive play for rounds 2 through 5 in session 2. The solid square shows the probability
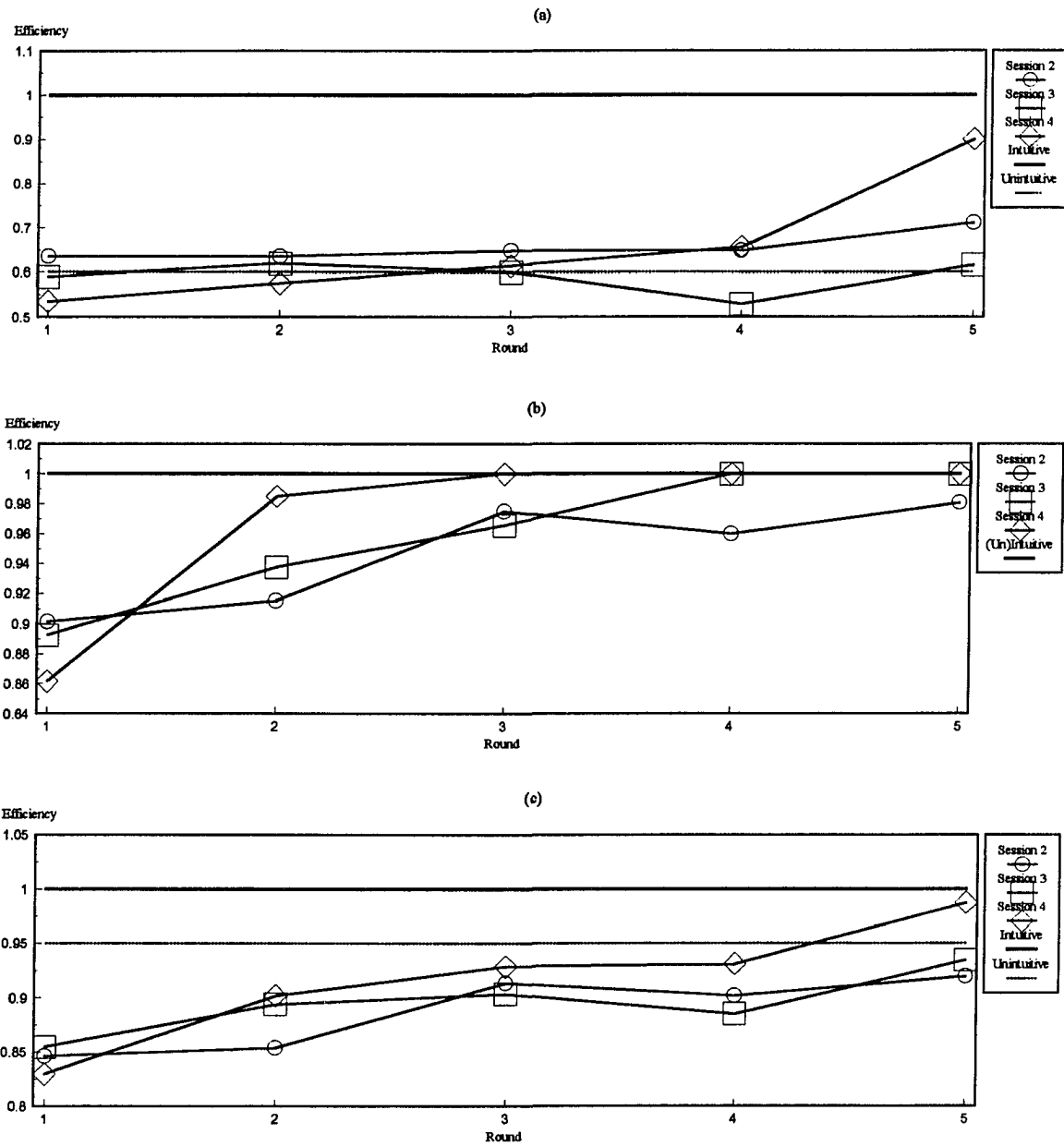
Figure 12: (a) Average efficiency for the A1s by session and round
(b) Average efficiency for the A2s by session and round
(c) Average efficiency for the Bs by session and round

Probability of intuitive play
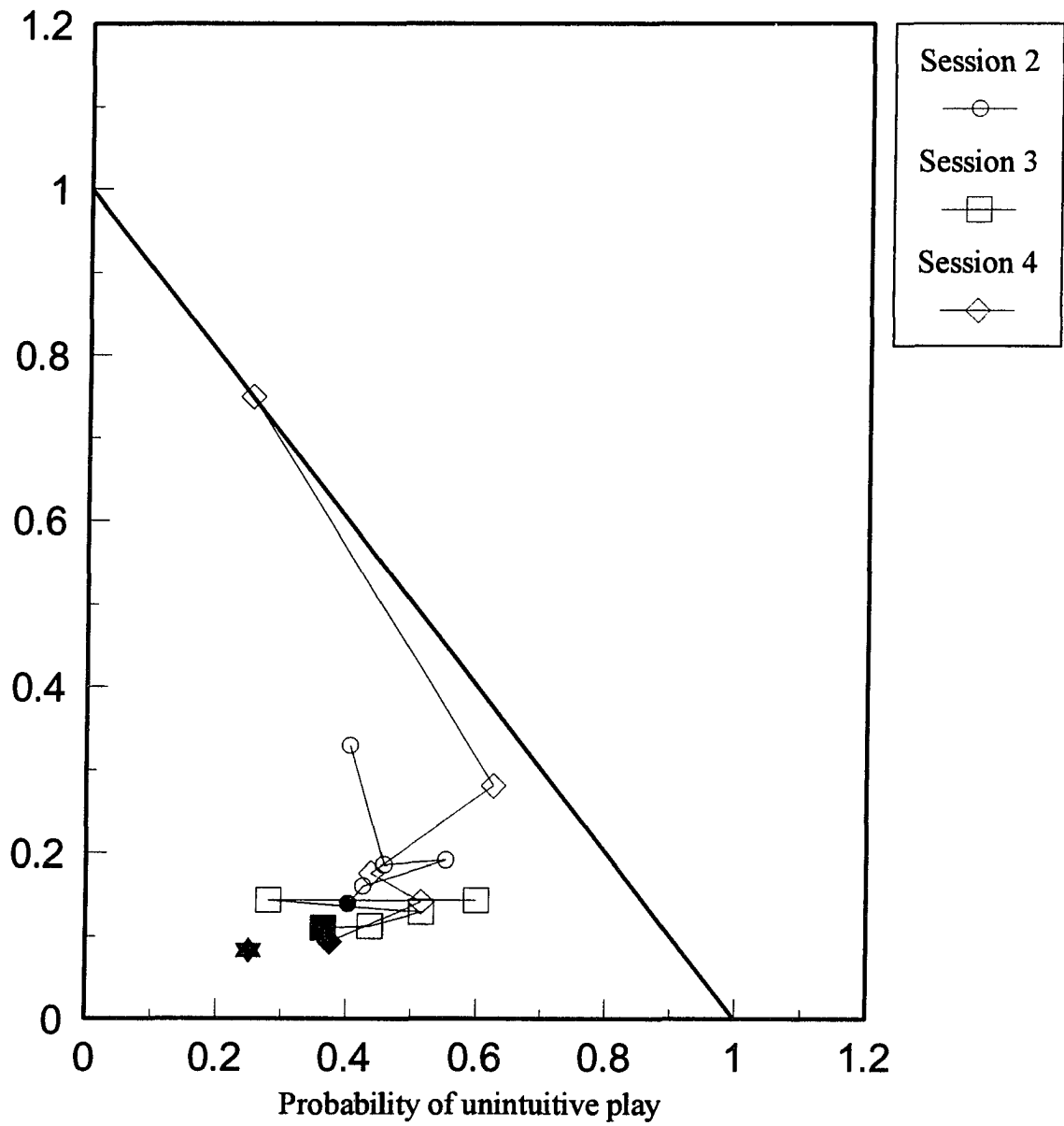
Figure 13: Experimental game dynamics by session

of intuitive and unintuitive play for round 1, session 3. This solid square is followed by a sequence of open squares denoting the probability of intuitive and unintuitive play for rounds 2 through 5 in session 3. The solid diamond shows the probability of intuitive and unintuitive play for round 1, session 4. This solid diamond is followed by a sequence of open diamonds denoting the probability of intuitive and unintuitive play for rounds 2 through 5 in session 4.

With the exception of one observation in each session, the sequence of observations for each session tend to move towards the boundary of the simplex connecting (0,1.0) to (1.0,0). This suggest a dynamic path moving in the direction of equilibrium behavior. For all three session, the dynamic path seems to initially move in the direction of the unintuitive equilibrium. However, while the final observation for round 5 in session 3 seems to continue along this path, the final observations for round five in sessions 2 and 4 seem to turn towards the intuitive equilibrium. These paths are more apparent if the observations for round 4 in sessions 2 and 3 and round 3 in session 4 are regarded as being outliers.

These outliers are explained by recalling Figure 11. In session 2, the increase in the probability that the A2s chose R in Round 4 [see Figure 11 (b)] leads to the decrease in the probabilities of the intuitive equilibrium and unintuitive equilibrium seen in Figure 13. In session 3, the strong increase in the probability that the A1s chose R in Round 4 [see Figure 11 (a)] coupled with the slight decrease in the probability that the Bs chose U in Round 4 [see Figure 11 (c)] leads to the slight increase in probability of the intuitive equilibrium and the strong decrease in probability of the unintuitive equilibrium seen in Figure 13. In session 4, the increase in the probability that the A1s chose R in Round 3 [see Figure 11 (a)] leads to the

increase in the probability of the intuitive equilibrium and the decrease in the probability of the unintuitive equilibrium seen in Figure 13.

Figure 14 reports the efficiency for all subjects by session and round. First, with a few exceptions, efficiency generally increased by round. Second, in earlier rounds, efficiency was lower than if all subjects had played the unintuitive equilibrium. However, by round 4, the session 4 subjects' efficiency surpasses the efficiency of the unintuitive equilibrium, and by round 5, the session 2 subjects' efficiency surpasses the efficiency of the unintuitive equilibrium. By round 5, the session 3 subjects' efficiency just equals the efficiency of the unintuitive equilibrium. Finally, notice that the outliers in Round 4 for sessions 2 and 3 correspond to a decrease in efficiency. However, the outlier in Round 3 for session 4 did not lead to a similar decrease in efficiency.

Statistical methods

Define P_{A1}, P_{A2} and P_B as the probability A1 chooses L, A2 chooses L and B chooses U in any given round.[45] Assume that these probabilities are identical for all players of the same type. Define G as the number of games in a round, g as the game number, N as the number of players of each type in a round, n as the player's number, and t as the player's type. Define $x^t_{n,g} = 1$ if the nth t type player chooses L in game g where t = A1 or A2. Otherwise, $x^t_{n,g} = 0$. Define $x^B_{n,g} = 1$ if the nth B type player chooses U in game g. Otherwise, $x^B_{n,g} = 0$. Assuming $x^t_{n,g}$ are independent for all t, n and g implies that $x^t_{n,g}$ has a Bernoulli distribution

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[45] Since the control variable differs by round, each round is considered a single observation.
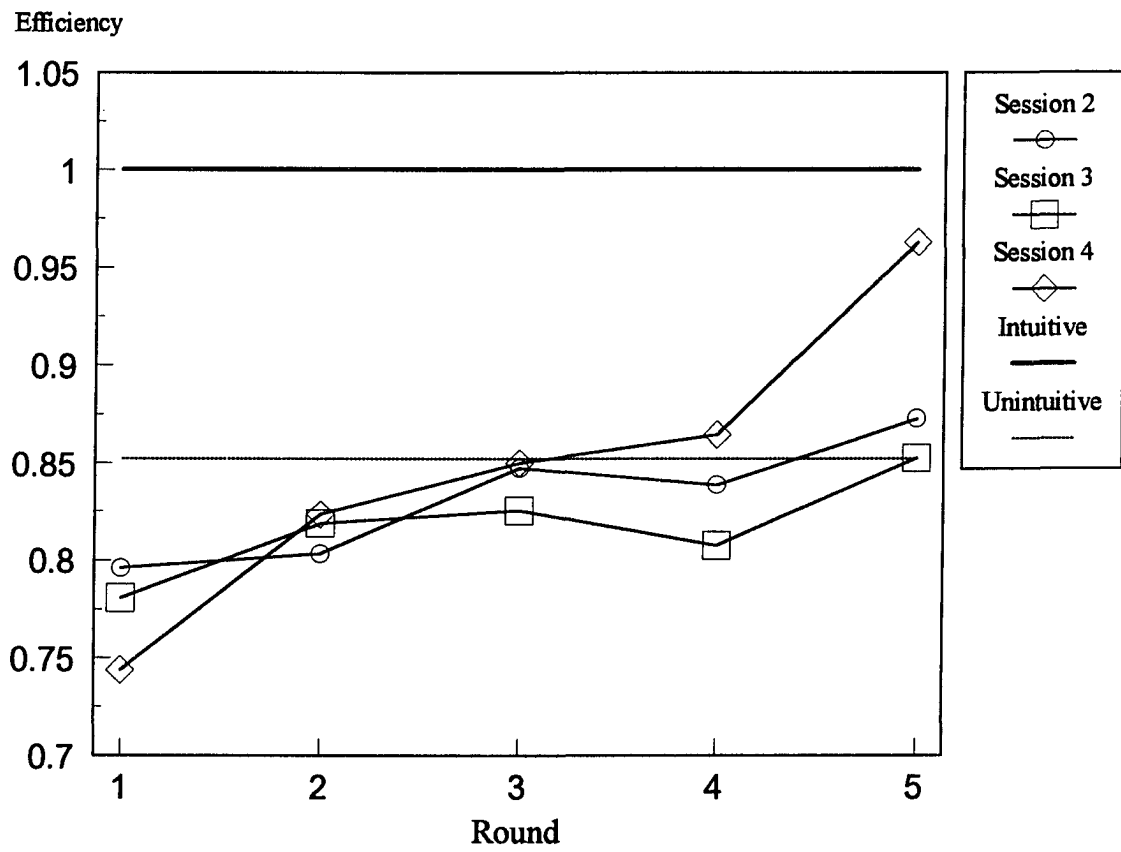
Efficiency

Figure 14: Average efficiency for all of the subjects by session and round

with parameter P_t and maximum likelihood estimate $\hat{P}_t = \dfrac{x'}{NG}$ where $x' = \sum\limits_{n=1}^{N}\sum\limits_{g=1}^{G} x'_{n,g}$.[46] The

distribution of $\hat{P}_t$ is then $\Pr\left(\hat{P}_t = \kappa_t | P_t\right) = \begin{pmatrix} NG \\ NG\kappa_t \end{pmatrix}\left(P_t\right)^{NG\kappa_t}\left(1 - P_t\right)^{NG(1-\kappa_t)}$ where

$\kappa_t = 0, \dfrac{1}{NG}, \dfrac{2}{NG},...,1$.

Define T_i and T_u to be the probability that the unintuitive and intuitive equilibria are

played given P_{A1}, P_{A2} and P_B. That is, $T_i = (1-P_{A1})P_{A2}P_B$ and $T_u = P_{A1}P_{A2}$. Substituting $\hat{P}_t$ for

$t = A1$, A2 and B yields the statistics $\hat{T}_i = \left(1 - \hat{P}_{A1}\right)\hat{P}_{A2}\hat{P}_B$ and $\hat{T}_u = \hat{P}_{A1}\hat{P}_{A2}$. $\hat{T}_i$ and $\hat{T}_u$ are

jointly distributed with a non-zero covariance. This distribution can be constructed by

summing $\prod_{t=\{A1,A2,B\}}\Pr\left(\hat{P}_t = \kappa_t | P_t\right)$ for all κ_{A1}, κ_{A2} and κ_B that yield the same values for $\hat{T}_i$

and $\hat{T}_u$.[47] This joint distribution is completely specified given the parameters P_{A1}, P_{A2} and P_B

and is used to test a number of null hypotheses regarding $\hat{T}_i$ and $\hat{T}_u$.

I also use the paired-sign test and the Mann-Whitney U test to test for differences

across sessions and rounds. These nonparametric tests are appropriate for the sample size and

the unknown error structure assuming independent observations.[48]

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[46] A common game theoretic assumption is that when an agent plays a mixed strategy the agent randomizes based on the mixing probabilities. This randomization implies that observations for a given subject are independent within a round and across rounds provided that the experimental design preserves the one-shot game incentives. However, if this is not the case, then dependence of a subject's actions within a round and across rounds may reduce the reliability of the statistical tests reported.

[47] There are $(NG)^3$ distinct combinations of κ_{A1}, κ_{A2} and κ_B that produce a variety of unique combinations of $\hat{T}_u$ and $\hat{T}_i$.

[48] As a consistency check, mean effects for rounds and sessions were also estimated using a probit model for each subject type where intuitive play in each game was the dependent variable and session dummies and the round number were the independent variables.

The paired-sign test uses independently drawn paired observations from two populations to test if the median difference in the two populations is 0. In addition, the paired-sign test assumes continuity around the median such that the probability that the median occurs is 0. This test counts the number of times the difference in the paired observations exceeds 0. If the null hypothesis is correct, then the probability that the difference in the paired observations is positive is equal to 1/2. Therefore, when the number of positive differences is high or low relative to the total number of paired observations, the null hypothesis is rejected.[49]

The Mann-Whitney U test uses independent random samples drawn from two populations to determine if the two populations are identical or deviate systematically. Besides independence, the Mann-Whitney U statistic assumes that the underlying probability distribution is continuous. This statistic orders the observations from both populations by magnitude and then considers whether this order is random, or whether the magnitude of the observations from first population seem to be in general higher or lower than the magnitude of the observations from the second population. If the null hypothesis is correct, the probability that any observation from first population exceeds any observation from the second population is 1/2. Therefore, when observations from the first population predominantly greater than or less than observations from the second population, the null hypothesis is rejected.[50]

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[49] For a more complete discussion of the paired-sign test, see Gibbons (1985) pp. 100-106.
[50] For a more complete discussion of the Mann-Whitney U test, see Gibbons (1985) pp. 140-149.

Statistical tests

Consider H_O: $T_i = 1$ versus H_A: $T_i < 1$. This hypothesis states that the subjects played

the intuitive equilibrium with probability 1.0. If the null hypothesis is correct, then $P_{A1} = 0$,

$P_{A2} = 1$, and $P_B = 1$. The null hypothesis is rejected at any level of significance because

$\hat{T}_i < 1.0$ for all observations (see Table 5). Under the null hypothesis, the probability that any

one observation is less than 1.0 is 0. The probability that one or more of the fifteen

observations is less than 1.0 is also 0. The rejection of the null hypothesis for all observations

implies that subject play was not intuitive.

Consider H_O: $T_u = 1$ versus H_A: $T_u < 1$. This hypothesis states that subjects play the

unintuitive equilibrium with probability 1.0. If the null hypothesis is correct, then $P_{A1} = 1$, and

$P_{A2} = 1$. The null hypothesis is rejected for all rounds taken independently or jointly at any

level of significance because $\hat{T}_u < 1$ for all observations (see Table 5). Under the null

hypothesis, the probability that any one observation is less than 1.0 is 0. The probability that

one or more of the fifteen observations is less than 1.0 is also 0. The rejection of the null

hypothesis for all observations implies that subject play was not unintuitive.

These first two hypotheses provide a stringent test for intuitive and unintuitive

equilibrium behavior. In fact, the null hypothesis is accepted only if all subjects choose to play

the same equilibrium in any given round. If any subject errors or different subjects play a

different equilibrium, then the H_O: $T_i = 1$, and H_O: $T_u = 1$ are rejected.

A weaker test that can be constructed is a test for random play. For instance, assume

that subjects choose randomly between actions with equal probability (i.e. $P_{A1} = 1/2$, $P_{A2} =$

Table 5: Cumulative probabilities under the null hypothesis that subjects choose actions randomly

Session	Round	$\hat{T}_l$	$\hat{T}_u$	Column 1[a]	Column 2[b]	Column 3[c]
2	1	0.139	0.403	0.9352*	0.9698**	0.9061***
2	2	0.161	0.426	0.9724	0.9842**	0.9568**
2	3	0.191	0.552	0.9934	0.9998*	0.9933*
2	4	0.186	0.458	0.9915*	0.9939*	0.9854**
2	5	0.330	0.405	1.0000*	0.9737**	0.9737**
3	1	0.111	0.365	0.8102	0.9411***	0.7599
3	2	0.113	0.437	0.8189	0.9924*	0.8121
3	3	0.130	0.515	0.9043***	0.9990*	0.9033***
3	4	0.144	0.28	0.9452***	0.6733	0.6334
3	5	0.144	0.6	0.9452***	1.0000*	0.9452***
4	1	0.094	0.375	0.6742	0.9703**	0.6523
4	2	0.142	0.515	0.9600**	0.9998*	0.9598**
4	3	0.176	0.438	0.9615**	0.9750**	0.9370***
4	4	0.281	0.625	.9854**	0.9894**	0.9748**
4	5	0.75	0.25	0.9992*	0.4961	0.4955

[a] Column 1 reports the joint cumulative probability that an observation for T_i is less than $\hat{T}_l$ under the null hypothesis that $P_{A1} = 1/2$, $P_{A2} = 1/2$ and $P_B = 1/3$.

[b] Column 2 reports the joint cumulative probability that an observation for T_u is less than $\hat{T}_u$ under the null hypothesis that $P_{A1} = 1/2$, $P_{A2} = 1/2$ and $P_B = 1/3$.

[c] Column 3 reports the joint cumulative probability that an observation for T_u and T_i is less than $\hat{T}_u$ and $\hat{T}_l$ under the null hypothesis that $P_{A1} = 1/2$, $P_{A2} = 1/2$ and $P_B = 1/3$.

* Significant at the one percent level.

** Significant at the five percent level.

*** Significant at the ten percent level.

1/2, and $P_B = 1/3$). If this assumption is correct, then the payoff structure and the experimental design had no influence on the subjects' decisions. Under the assumption of random behavior, there are three possible hypotheses. Since non-random play is expected to be intuitive or unintuitive, these hypotheses are H_O: $T_i = 0.083$ versus H_A: $T_i > 0.083$, H_O: $T_u = 0.25$ versus H_A: $T_u > 0.25$, and H_O: $T_i = 0.083$ and $T_u = 0.25$ versus H_A: $T_i > 0.083$ and $T_u > 0.25$. The first two hypotheses independently test random play versus intuitive or unintuitive play, while the third hypothesis jointly tests random play versus intuitive and unintuitive play.

First, consider H_O: $T_i = 0.083$ versus H_A: $T_i > 0.083$. In 7 of the 15 rounds, the hypothesis is rejected at the five percent level (see Table 5, Column 1). Therefore, the hypothesis is rejected for entire set of 15 observations. Taking each round individually, an observation is rejected if the joint cumulative probability of the observation under the null hypothesis is greater than 0.95. Under the null hypothesis, the probability of rejecting 2 or fewer of the 15 observations at a five percent level is 0.96. This suggests that $T_i > 0.083$ or that subject play was non-random and in the direction of the intuitive equilibrium.

Second, consider H_O: $T_u = 0.25$ versus H_A: $T_u > 0.25$. In 12 of the 15 rounds, the hypothesis is rejected at the five percent level (see Table 5, Column 2). Therefore, the hypothesis is rejected for entire set of 15 observations. Taking each round individually, an observation is rejected if the joint cumulative probability of the observation under the null hypothesis is greater than 0.95. Under the null hypothesis, the probability of rejecting 2 or fewer of the 15 observations at a five percent level is 0.96. This suggests that $T_u > 0.25$ or that subject play was non-random and in the direction of the unintuitive equilibrium.

Third, consider H_O: $T_i = 0.083$ and $T_u = 0.25$ versus H_A: $T_i > 0.083$ and $T_u > 0.25$. In

6 of the 15 rounds, the hypothesis is rejected at the five percent level (see Table 5, Column 3).

Therefore, the hypothesis is rejected for entire set of 15 observations. Taking each round

individually, an observation is rejected if the joint cumulative probability of the observation

under the null hypothesis is greater than 0.95. Under the null hypothesis, the probability of

rejecting 2 or fewer of the 15 observations at a five percent level is 0.96. This suggests that T_i

> 0.083 and $T_u > 0.25$ or that subject play was non-random and in the direction of the intuitive

and unintuitive equilibria.

The first 5 hypotheses tested suggest several conclusions. Subjects did not play

strictly intuitively or strictly unintuitively. However, subjects did not play randomly either. In

general, the subjects played in the direction of both the intuitive and unintuitive equilibria.[51]

Systematic differences between rounds, sessions and incentive mechanisms are now

considered. Since sessions 2 and 3 are identical accept for the subject pool and the history,

these two sessions are compared first.

Pairing the observations by round for sessions 2 and 3, consider H_O: The median

difference in T_i between sessions 2 and 3 is equal to 0 versus H_A: The median difference in T_i

between sessions 2 and 3 is not equal to 0. The null hypothesis is rejected at the five percent

level because 5 of the 5 differences are positive. At the five percent level, the null hypothesis is

rejected for the paired-sign test when all of the differences are positive or all of the differences

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[51] Probit analysis indicates that the A1s played randomly, that the A2s played in the direction of their
equilibrium action, and that the Bs played in the direction of the intuitive and unintuitive equilibria in sessions
2 and 4, and randomly in session 3.

are negative. The rejection of H_O suggests that there was a statistical difference in the probability of intuitive play between sessions 2 and 3.

Grouping the data by session, consider H_O: T_i is identically distributed across sessions 2 and 3 versus H_A: T_i is not identically distributed across sessions 2 and 3. The null hypothesis is rejected at the five percent level because the Mann-Whitney U statistic is 23. At the five percent level, the null hypothesis is rejected for the Mann-Whitney U test if the Mann-Whitney U statistic is less than or equal to 2, or greater than or equal to 23. The rejection of H_O suggests that there was a statistical difference in the probability of unintuitive play between sessions 2 and 3.

Pairing the observations by round for sessions 2 and 3, consider H_O: The median difference in T_u between sessions 2 and 3 is equal to 0 versus H_A: The median difference in T_u between sessions 2 and 3 is not equal to 0. The null hypothesis is not rejected at the five percent level because 3 of the 5 differences are positive. At a five percent level, the null hypothesis is rejected for the paired-sign test when all of the differences are positive or all of the differences are negative. The failure to reject H_O suggests that there was no statistical difference in the probability of unintuitive play between sessions 2 and 3.

Grouping the data by session, consider H_O: T_u is identically distributed across sessions 2 and 3 versus H_A: T_u is not identically distributed across sessions 2 and 3. The null hypothesis is not rejected at the five percent level because the Mann-Whitney U statistic is 13. At the five percent level, the null hypothesis is rejected for the Mann-Whitney U test if the Mann-Whitney U statistic is less than or equal to 2, or greater than or equal to 23. The failure

to reject H_O suggests that there was no statistical difference in the probability of unintuitive play between sessions 2 and 3.

The rejection the null hypotheses for a difference in the probability of intuitive play between sessions 2 and 3, and the failure to reject the null hypotheses for a difference in the probability of unintuitive play between sessions 2 and 3 provide inconclusive support for differences in subject play between sessions 2 and 3. In order to test if a jointly significant difference exits, the joint cumulative probability of $\hat{T}_i$, and $\hat{T}_u$ is calculated, and a paired-sign tests and Mann-Whitney U tests are performed on these joint cumulative probabilities paired by round and grouped by session.

Recall that values for P_{A1}, P_{A2} and P_B must be specified in order to calculate the joint cumulative probability of $\hat{T}_i$, and $\hat{T}_u$. These values are specified using the maximum likelihood estimates for the pooled data under three alternative assumptions. First, P_{A1}, P_{A2}, and P_B are assumed to be invariant across rounds and sessions such that maximum likelihood estimates are obtained by pooling the data by session and round.[52] Second, P_{A1}, P_{A2}, and P_B are assumed to be invariant across rounds but not across sessions such that maximum likelihood estimates are obtained by pooling the data by round. Third, P_{A1}, P_{A2}, and P_B are assumed to be invariant across sessions but not across rounds such that maximum likelihood estimates are obtained by pooling the data by session. Table 6, Columns 1, 2 and 3 report the joint cumulative probability of $\hat{T}_i$, and $\hat{T}_u$ by session, round and assumption. Column 1 corresponds

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[52] The maximum likelihood estimates used for the alternative hypothesized values of P_{A1}, P_{A2}, and P_B are reported in notes to Table 6.

Table 6: Tests for differences across sessions and rounds for sessions 2 and 3

Session	Round	$\hat{T_l}$	$\hat{T_u}$	Column 1[a]	Column 2[b]	Column 3[c]
2	1	0.139	0.403	0.0518	0.0165	0.3206
2	2	0.161	0.426	0.1238	0.0507	0.2594
2	3	0.191	0.552	0.5407	0.3730	0.3076
2	4	0.186	0.458	0.2759	0.1684	0.3976
2	5	0.330	0.405	0.3293	0.3068	0.1137
3	1	0.111	0.365	0.0076	0.0348	0.1229
3	2	0.113	0.437	0.0313	0.1119	0.1151
3	3	0.130	0.515	0.1456	0.3387	0.0502
3	4	0.144	0.28	0.0027	0.0108	0.0175
3	5	0.144	0.6	0.3137	0.5662	0.0342
Paired-Sign Test		5*	3	5*	2	5*
Mann-Whitney U		23*	13	20**	13	23*

[a] Column 1 reports the joint cumulative probability that an observation for T_u and T_i is less than $\hat{T_u}$ and $\hat{T_i}$ under the null hypothesis that $P_{A1} = 0.512$, $P_{A2} = 0.872$ and $P_B = 0.396$.

[b] Column 2 reports the joint cumulative probability that an observation for T_u and T_i is less than $\hat{T_u}$ and $\hat{T_i}$ under the null hypothesis that $P_{A1} = 0.536$, $P_{A2} = 0.84$ and $P_B = 0.504$ for session 2 and $P_{A1} = 0.488$, $P_{A2} = 0.904$ and $P_B = 0.288$ for session 3.

[c] Column 3 reports the joint cumulative probability that an observation for T_u and T_i is less than $\hat{T_u}$ and $\hat{T_i}$ under the null hypothesis that $P_{A1} = 0.52$, $P_{A2} = 0.74$ and $P_B = 0.36$ for round 1, $P_{A1} = 0.54$, $P_{A2} = 0.8$ and $P_B = 0.38$ for round 2, $P_{A1} = 0.58$, $P_{A2} = 0.92$ and $P_B = 0.42$ for round 3, $P_{A1} = 0.4$, $P_{A2} = 0.94$ and $P_B = 0.32$ for round 4, and $P_{A1} = 0.52$, $P_{A2} = 0.96$ and $P_B = 0.5$ for round 5.

* Significant at the five percent level for a two-tail test.

** Significant at the ten percent level for a one-tail test.

to the assumption of invariance across rounds and sessions. Column 2 corresponds to the assumption of invariance across rounds, and Column 3 corresponds to the assumption of invariance across sessions. The paired-sign statistics and the Mann-Whitney U statistics are also reported at the bottom of each column in Table 6.

Pairing the observations in Columns 1, 2 and 3 by round, consider H_O: The median difference in the joint cumulative probability of $\hat{T}_i$, and $\hat{T}_u$ between sessions 2 and 3 is equal to 0 versus H_A: The median difference in the joint cumulative probability of $\hat{T}_i$, and $\hat{T}_u$ between sessions 2 and 3 is not equal to 0. The null hypothesis is rejected at the five percent level for Columns 1 and 2 because 5 of the 5 differences are positive. The null hypothesis is not rejected at the five percent level for Column 2 because 2 of the 5 differences are positive. At a five percent level, the null hypothesis is rejected for the paired-sign test when all of the differences are positive or all of the differences are negative. The rejection of H_O for Columns 1 and 3, and failure to reject H_O for Column 2 suggest that there were statistically significant differences between sessions 2 and 3, but not across rounds within a session.

Grouping the observations in Columns 1, 2 and 3 by session, consider H_O: The joint cumulative probability of $\hat{T}_i$, and $\hat{T}_u$ is identically distributed across sessions 2 and 3 versus H_A: The joint cumulative probability of $\hat{T}_i$, and $\hat{T}_u$ is not identically distributed across sessions 2 and 3. The null hypothesis is not rejected at the five percent level for Columns 1 and 2 because the Mann-Whitney U statistics are 20 and 13, respectively. The null hypothesis is rejected for Column 3 because the Mann-Whitney U statistic is 23. At the five percent level, the null hypothesis is rejected for the Mann-Whitney U test if the Mann-Whitney U statistic is

less than or equal to 2, or greater than or equal to 23. The failure to reject H_O for Columns 1 and 2 and the rejection of H_O for Column 3 suggest that there is some statistical evidence to support differences between sessions, but not across rounds within a session.

The results of the paired-sign tests and Mann-Whitney U tests in Columns 1,2 and 3 suggest that there are differences across sessions in the median differences of the joint cumulative probabilities and in the distribution of the joint cumulative probabilities. Extending these results to suggest that these same differences exist across sessions but not across rounds for P_{A1}, P_{A2}, and P_B, must be done cautiously because the distribution of the joint cumulative probabilities will generally differ for different null hypotheses regarding P_{A1}, P_{A2}, and P_B. Therefore, the reported levels of significance should be regarded as suggestive and not exact. Finally, while the general assumptions of game theory imply that observations are independent if subjects are treating each game as a one-shot game, this assumption should be treated cautiously in the dynamic context of the experiment. Therefore, the nonparametric tests for differences across sessions and rounds should be considered cautiously.[53]

To test for differences due to alternative incentive mechanisms, only the first two rounds in sessions 4 are considered because these rounds contained the entire population of tournament participants. For comparison, the analysis is also considers the first two rounds of sessions 2 and 3. Pooling rounds 1 and 2 for sessions 2, 3 and 4, the maximum likelihood

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[53] Probit analysis suggests that there are no differences across rounds or sessions for the A1s, that there are differences across rounds and sessions for the A2s, and that there are differences across sessions for the Bs.

Table 7: Test for differences across session 2, 3 and 4 and rounds 1 and 2

Session	Round	Column 1[a]
2	1	0.2057
2	2	0.3379
3	1	0.0588
3	2	0.1720
4	1	0.0286*
4	2	0.5452

[a] Column 1 reports the joint cumulative probability that an observation for T_u and T_i is less than $\hat{T}_u$ and $\hat{T}_i$ under the null hypothesis that $P_{A1} = 0.524$, $P_{A2} = 0.81$ and $P_B = 0.331$.

* Significant at the ten percent level.

estimates are obtained for the hypothesized values of P_{A1}, P_{A2}, and P_B.[54] Table 7 reports the

joint cumulative probabilities of $\hat{T}_u$, and $\hat{T}_i$ by session and round.

Consider H_O: $P_{A1} = 0.524$, $P_{A2} = 0.81$ and $P_B = 0.331$ versus H_A: $P_{A1} \neq 0.524$, $P_{A2} \neq$

0.81 and $P_B \neq 0.331$. At the five percent level of significance, the null hypothesis is not

rejected for any of the observations. Considering the set of six observation, the null

hypothesis can not be rejected at the five percent level of significance. Taking each round

individually, an observation is rejected if the joint cumulative probability of the observation

under the null hypothesis, is greater than 0.975 or less than 0.025. Under the null hypothesis,

the probability of rejecting 1 or more of the 6 observations at a five percent level is 0.98. The

rejection of H_O suggests that the tournament did not significantly change the subjects play.[55]

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[54] The estimated hypothesized values of P_{A1}, P_{A2}, and P_B are reported in the notes to Table 7.

[55] Probit analysis also failed to provide support for the assertion that the tournament encouraged more rapid learning.

Discussion

While there is not enough concrete statistical evidence to conclude that the intuitive

equilibrium predicts aggregate subject behavior any better than the unintuitive equilibrium,

there is enough statistical evidence to conclude that aggregate subject behavior is non-random

and in the general direction of the intuitive and unintuitive equilibria. There is also sufficient

statistical evidence to conclude that that there was significant difference in aggregate subject

behavior between sessions 2 and 3.

While aggregate behavior was non-random and differed between sessions 2 and 3, a

closer look at the data reveals that these results do not hold for all subject types considered

independently. Table 2, Figure 11 (a) and probit analysis suggest that the A1s played

randomly in all sessions and rounds. Table 3, Figure 11 (b) and probit analysis suggest that

the A2s converged to equilibrium play at different rates in all three sessions. Table 4, Figure

11 (c) and probit analysis suggest that the Bs play was non-random in sessions 2 and 4 and

that differences in play existed across all three sessions. These results provide evidence to

support Plott's (1995) discovered preference hypothesis.

Plott's (1995) discovered preference hypothesis asserts that experimental subjects

move through three stages of rationality when confronted with a new or unfamiliar task. In

the first-stage, subjects play seems random or without purpose. During this stage, subjects

are becoming familiar with the experimental environment. In the second-stage, subject

behavior becomes more purposeful, and this purpose starts to reveal the subject's preferences.

In the third-stage, subject behavior becomes sophisticated. Subjects' actions reveal well

developed preferences and an anticipation for other subjects' actions. Plott (1995) asserts that

these three stages generally serve to describe subject behavior in an experiment. He also asserts that not all subjects will encounter all three stages of rationality in any given experiment. Some agents may start in the first-stage of rationality and never advance beyond this stage, while other agents may start in later stages or move quickly through all three stages.

This discovered preference hypothesis can explain the general behavior of the subjects in the SLAPP experiment. In early rounds, about 50.0% of the A2s started off playing in equilibrium. All but one of the A2s moved to equilibrium play by Round 5. This suggests that about half of the A2s started in Plott's third-stage of rationality. The remaining A2s started in Plott's first-stage of rationality and all but one quickly advanced to Plott's third-stage of rationality. Through all five rounds, just over half of the Bs played pure strategies that suggest purposeful actions and Plott's second-stage of rationality. On average, just under a quarter of the Bs played an equilibrium strategy that was optimal given the A2s chose their equilibrium strategy. The proportion of Bs playing optimally given the A2s were playing in equilibrium generally increased in later rounds. By round 5, a majority of the subjects that had started in Plott's second-stage of rationality had made it to Plott's third-stage of rationality. Of the remaining Bs, half seemed to still be in Plott's first-stage of rationality by round 5 while the other half seemed to have reached Plott's second-stage of rationality by Round 5. Through all five rounds in all three sessions, the A1s generally played randomly or without an apparent purpose suggesting Plott's first-stage of rationality.

The A2s and the Bs generally seemed to progress through Plott's three stages of rationality, while the A1s showed little advancement past Plott's first-stage of rationality.

Recalling Figure 12 (a), the A1s' average efficiency given their random play was generally as high as or higher than the average efficiency of playing unintuitively. This suggest that the A1s payoffs were not salient. By improving the saliency of the A1s payoffs and providing subjects with additional rounds to learn, conclusive support for the intuitive or unintuitive equilibrium should be obtained.

CONCLUSIONS

Summary

The primary purpose of this dissertation is to construct a game theoretic model to explore the economic incentives encouraging strategic lawsuits against public participation (SLAPPs), and to explore the efficiency consequences of eliminating SLAPPs. This model is a two-stage contest with asymmetric incomplete information regarding agents' benefits. Using the perfect Bayesian equilibrium concept, equilibrium behavior is characterized assuming a ratio contest success function with asymmetric ability. Comparative static results are derived for the second-stage of the contest, and efficiency is evaluated using contest efficiency (see Appendix B) as the primitive measure of efficiency. Given the general ambiguity of the efficiency results, the contest success function is parameterized and efficiency is evaluated for a wide range parameter values assuming that the firm has normal *a priori* beliefs regarding the distribution of the homeowner's benefit from winning the contest. Finally, the predictive power of the perfect Bayesian equilibrium is tested using experimental methods and of a specific form of the SLAPP game.

First, the analysis suggests that the firm's and homeowner's equilibrium levels of effort in the second-stage of the game and equilibrium actions in the first-stage of the game depend crucially on a measure of each agent's relative strength which is referred to as relative resolve. With the ratio form of the contest success function, an agent's relative benefit and relative ability contribute equally to the agent's relative resolve. Intuitively, this result implies that an agent's strength determines an agent's equilibrium actions, and whether this strength comes from a strong desire to win or natural ability is irrelevant.

Equilibrium effort in the second-stage of the game is determined by the sequence of play in the first-stage of the game, by relative resolve and by the firm's expected relative resolve given its incomplete information. The proportion of the leader's benefit that the leader dissipates in equilibrium is determined by relative resolve when the leader's information is complete and by expected relative resolve when the leader's information is incomplete. The follower's equilibrium effort is determined by the follower's best response function and the proportion of the leader's benefit that the leader dissipates in equilibrium. The shape of the follower's best response function depends on whether the leader's effort is a strategic complement or substitute to the follower. That is, when the leader's effort is a strategic complement (substitute) to the follower, the follower's best response function is increasing (decreasing) in the leader's effort. Therefore, strategic complementarity and substitutability play an important role in determining equilibrium efforts. When agents move simultaneously, the agent with incomplete information exhibits leader type behavior because equilibrium efforts will generally fall off this agent's best response function. The agent with complete information exhibits follower type behavior because equilibrium efforts will lie on this agent's best response function.

Equilibrium timing decisions in the first-stage of the game also depend on relative resolve and the firm's expected relative resolve given its incomplete information. In the SLAPP game, the firm's incomplete information leads to timing decisions that would not occur if the firm had complete information. Some homeowners' types that would normally choose Sue because of their low relative resolve now choose Squawk to take advantage of the firm's mis-perception that these homeowners' types are stronger than they actually are. Some

homeowners' types that would normally choose Squawk because of their high relative resolve now choose Sue because of the firm's mis-perception that these homeowners' types are weaker than they actually are. When SLAPPs are eliminated, similar incentives exist for some homeowners' types to exploit the firm's incomplete information. However, the parameterized model suggests that these incentives are insignificant. That is, in the SLAPP-free game, equilibrium behavior is the same whether or not the firm's information is incomplete because information effects are weak.

Second, efficiency depends on relative resolve and the firm's expected relative resolve given its incomplete information to the extent that these factors influence equilibrium efforts. Whether this equilibrium effort is efficient depends on relative benefits and relative abilities. *Ex post* efficiency is higher when the agent with high (low) relative benefit has high (low) relative ability. Efficiency is lower when the agent with high (low) relative benefit has low (high) relative ability. Therefore, it is efficient for an agent with high relative resolve to employ high amounts of effort only if the agent's high relative resolve is due partially to high relative benefits.

Third, under the parameterizations considered here, the SLAPP game is always at least as efficient as the SLAPP-free game *ex ante*. In a complete information contest, it is most efficient for the relatively weak agent to lead in an attempt to reduce the amount of equilibrium effort expended by a the relatively strong agent (see Baik and Shogren 1992). If timing decisions are endogenous, then the relatively weak agent will choose to lead and the relatively strong agent will choose to follow. Eliminating SLAPPs has the effect of eliminating the ability of the weak agent to choose her preferred and most efficient action.

Incomplete information weakens this result slightly, but does not change this result when a ratio contest success function is specified and the firm's beliefs are normally distributed.

Fifth, in some instances, the parameterized model leads to multiple equilibria in the SLAPP game. An experimental test using a specific form of the SLAPP game provided little concrete statistical support for either of these two perfect Bayesian equilibria. There is concrete statistical support for non-random play in the direction of these equilibria and for differences between session where sessions varied only by the subject pool and by the history revealed to the subjects. There is also evidence to support Plott's (1995) discovered preference hypothesis.

Recommendations

Contests are inherently inefficient because agents expend non-productive resources attempting to secure a prize or property right. Three factors serve to exacerbate the inherent inefficiency of the contest considered here. First, the contest tends to be less efficient when the agent with the highest relative resolve strategically commits effort. Second, asymmetric incomplete information generally reduces efficiency. Third, when the contests is between an agent with a high relative benefit and low relative ability and an agent with a low relative benefit and a high relative ability, efficiency tends to be lower.

In the model presented here, the elimination of SLAPPs represents the elimination of the ability of an uninformed agent (the agent with incomplete information) to strategically commit effort. This does not affect the efficiency of the contest provided the uninformed agent has a relatively high benefit and ability and the informed agent (the agent with complete information) chooses to strategically commit effort. However, if the uninformed agent has a

low relative benefit and ability or the informed agent does not choose to strategically commit effort, then the efficiency of the contest will tend to be lower. Therefore, a policy that eliminates SLAPPs exacerbates the inherent inefficiency of the contest. If the policy goal is to maximize the efficiency of the contest, then SLAPPs should not be eliminated.

Efficiency in the contest presented here can also be improved by improving information. For instance, sponsoring research that values non-market resources and measures agents' abilities can create a pool of information that can be used to enhance efficiency. This pool of information can serve to enhance efficiency by improving the uninformed agent's information. This pool of information can also be used by policy makers to determine the primary characteristics of a non-market resource and of agents that signal the agents' benefits and abilities. If policy makers can influence relative ability, then the efficiency of the contest can be improved by using benefit information to design institutional mechanisms that augment the ability of the agent with the highest benefit.

Future Research

There are four important lines on which to extend this research. First, the model can be extended to consider alternative information structures. Second, the model can be expanded into a more general model of conflict resolution. Third, additional experiments can be conducted to test for hypothesized equilibrium behavior in games of incomplete information. Fourth, new empirical models can be constructed to improve the analysis of experimental data.

The contest model developed here restricts its attention to one-sided incomplete information regarding the homeowners benefit. In many instances, the assumption of two-

sided incomplete information is more appropriate. While two-sided incomplete information has been addressed for perfectly discriminating contest success functions (see Hillman and Riley 1989), I have not found research that explores the effect of two-sided incomplete information for imperfectly discriminating contest success function. The results above are applicable when an agent chooses to strategically commit effort. However, when agents move simultaneously, analyzing the agents' best response functions becomes troublesome. Recall that the firm's incomplete information lead the firm to exhibit leader type behavior. If both agent's have incomplete information, then both agents are likely to exhibit leader type behavior as in the complete information contest. The key to analyzing a solution for an imperfectly discriminating contest with two-sided incomplete information is likely be found in the leader-follower solution structure.

Another important area for future research is the extension of the source of incomplete information to include ability. To foreshadow the result, independent benefits and abilities will have little impact on the model, while positive or negative correlation will significantly impact levels of effort and efficiency. Positive correlation will most likely tend to improve efficiency and negative correlation will most likely tend to decrease efficiency because efficiency is higher when agents with a high benefit also have a high ability.

The contest explored here assumes that a contest is the only available conflict resolution mechanism. It is more likely that agents can choose from a list of conflict resolution mechanisms when deciding whether or not to enter a contest. For example, this list might include mediation, bribery and coercion. A more general model can be developed to

explore when it is efficient to have an inefficient contest that encourages agents to choose a more efficient alternative conflict resolution mechanism.

Future work must also continue to explore the predictive power of alternative game theoretic equilibrium concepts. However, before strong statistical results can be established, experimental methods must advance along with the statistical models used to analyze experimental data. The design presented here explicitly controls a subject's history, and risk attitudes due to randomization. It also samples a subject's beliefs and takes multiple samples of a subject's preferred action given these beliefs. The data provides an opportunity to decompose subject behavior into learning behavior and equilibrium behavior. The primary draw back of this experimental design is that it does not fully control for risk preferences when some subjects play out of equilibrium or in mixed strategies. Current methods of inducing risk neutral preferences are generally not sufficient to guarantee this result. Therefore, additional research must be done to develop more suitable methods for controlling risk attitudes and to test the efficacy of current methods. The basic game in this experiment can then be reparameterized to compare and test a number of perfect Bayesian equilibrium refinements.

To improve the statistical analysis of this experimental data, there are two distinct avenues to explore depending on the questions of interest. If the dynamic nature of subject behavior across rounds and sessions is of interest, a model that combines the basic elements of dynamic discrete choice models and static empirical models of discrete games is necessary [For examples, see Fisher and Nijkamp (1987), Eckstein and Wolpin (1989), Hotz, Miller and Smith (1994) and Breshnahan and Reiss (1991)]. If convergence towards a particular

equilibrium is of interest, a simpler nonparametric test that considers whether a sequence of observations is moving significantly towards a given point might suffice.

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APPENDIX A. PROOFS OF PROPOSITIONS 2 THROUGH 9

Proof of Proposition 2:

The ith agent's resolve is defined as $\rho_i = \sqrt{\varpi_i \alpha_i}$. Taking the partial derivative with

respect to the ith agent's relative benefit and relative ability yields $\dfrac{\partial \rho_i}{\partial \varpi_i} = \sqrt{\dfrac{\alpha_i}{4\varpi_i}} > 0$ and

$$\frac{\partial \rho_i}{\partial \alpha_j} = \sqrt{\frac{\varpi_i}{4\alpha_i}} > 0 .$$ Q.E.D.

Claim 1: The homeowner's equilibrium effort is a strategic complement (substitute) to the

firm in the Citizen suit subgame as $x_f > (<)\alpha_h \, x_h$, while the firm's equilibrium effort is a

strategic complement (substitute) to the firm in kth subgame as $x_f < (>)\alpha_h \, x_h$ where k = S or

N.

Proof of Claim 1: Bulow, Geanakoplos, and Klemperer (1985) define strategic complements

and substitutes based on how one agent's actions affect another agent's marginal profitability.

If an agent's action increases (decreases) another agent's marginal profitability, then the

agent's action is a strategic complement (substitute) to the other agent.

The firm's marginal profitability or payoff in the Citizen suit subgame is

$$\frac{\partial E\pi_f(x_f, x_h)}{\partial x_f} = \int_{v \in R} \left[V_f \left(\frac{\alpha_h \, x_h}{\left(x_f + \alpha_h \, x_h(v) \right)^2} \right) - 1 \right] d\Phi(v, \tau).$$ Taking the partial derivative of the

firm's marginal payoff with respect to the homeowner's effort yields

$$\frac{\partial^2 E\pi_f(x_f, x_h)}{\partial x_f \partial x_h(v)} = \int_{v \in R} V_f \left(\frac{\alpha_h(x_f - \alpha_h x_h)}{(x_f + \alpha_h x_h(v))^3} \right) d\Phi(v, \tau).$$ Therefore, the homeowner's effort is a

strategic complement (substitute) to the firm as $x_f > (<)\alpha_h x_h$.

The homeowner's marginal profitability or payoff in the kth subgame is

$$\frac{\partial E\pi_h(x_f, x_h)}{\partial x_h} = V_h \left(\frac{\alpha_h x_f}{(x_f + \alpha_h x_h)^2} \right) - 1$$ where k = S or N. Taking the partial derivative of

the homeowner's marginal payoff with respect to the firm's effort yields

$$\frac{\partial^2 E\pi_h(x_f, x_h)}{\partial x_h \partial x_f} = V_h \left(\frac{\alpha_h(\alpha_h x_h - x_f)}{(x_f + \alpha_h x_h)^3} \right).$$ Therefore, the firm's effort is a strategic

complement (substitute) to the homeowner as $x_f < (>)\alpha_h x_h$.   Q.E.D.

Claim 2: The firm's equilibrium effort in the kth subgame is a strategic complement

(substitute) to the homeowner as $1 > (<)2\rho_f \beta_k$ where k = S or N.

Proof of Claim 2: From the proof of claim one, the firm's effort is a strategic complement

(substitute) to the homeowner in the kth subgame as $x_f < (>)\alpha_h x_h$. Substituting $[x_f^k, x_h^k]$

from above then implies that the firm's equilibrium effort in the kth subgame is a strategic

complement (substitute) to the homeowner as $V_f \beta_k^2 < (>)\alpha_h \varpi_h V_f \left(\rho_f \beta_k - (\rho_f \beta_k)^2 \right)$ or,

rearranging terms, as $1 > (<)2\rho_f \beta_k$.   Q.E.D.

Proof of Proposition 3:

The partial derivatives of x_f^k and x_h^k with respect to τ are

$$\frac{\partial x_f^k}{\partial \tau} = 2V_f \beta_k \frac{\partial \beta_k}{\partial \tau}$$

and

$$\frac{\partial x_h^k}{\partial \tau} = V_h \left(\rho_f - 2\rho_f^2 \beta_k \right) \frac{\partial \beta_k}{\partial \tau}.$$

When $k = S$, $\dfrac{\partial \beta_S}{\partial \tau} = \dfrac{1}{2} \dfrac{\partial E_{\Phi_S}(\rho_f)}{\partial \tau} > 0$ by assumption. Therefore, $\dfrac{\partial x_f^S}{\partial \tau} > 0$ and

$\dfrac{\partial x_h^S}{\partial \tau} > (<)0$ as $1 > (<)2\rho_f \beta_S$ or , from claim 2, as the firm's equilibrium effort is a strategic

complement (substitute) to the homeowner.

When $k = N$, $\dfrac{\partial \beta_N}{\partial \tau} = \dfrac{\partial E_{\Phi_N}(\rho_f)}{\partial \tau} \left[\dfrac{1 - 2E_{\Phi_N}(\rho_f)\beta_N}{\left(1 + E_{\Phi_N}(\rho_f)^2 + Var_{\Phi_N}(\rho_f) \right)} \right] > (<)0$ as

$1 > (<)2E_{\Phi_N}(\rho_f)\beta_N$. Therefore, $\dfrac{\partial x_f^N}{\partial \tau} > (<)0$ as $1 > (<)2E_{\Phi_N}(\rho_f)\beta_N$. As $\dfrac{\partial x_f^N}{\partial \tau} > 0$,

$\dfrac{\partial x_h^N}{\partial \tau} > (<)0$ as $1 > (<)2\rho_f \beta_N$. As $\dfrac{\partial x_f^N}{\partial \tau} < 0$, $\dfrac{\partial x_h^N}{\partial \tau} > (<)0$ as $1 < (>)2\rho_f \beta_N$. From

claim 2, $1 > (<)2\rho_f \beta_N$ as the firm's equilibrium effort is a strategic complement (substitute)

to the homeowner.   Q.E.D.

Proof of Proposition 4:

The partial derivatives of x_f^k and x_h^k with respect to τ are

$$\frac{\partial x_f^k}{\partial \tau} = 2V_f \beta_k \frac{\partial \beta_k}{\partial \tau}$$

and

$$\frac{\partial x_h^k}{\partial \tau} = V_h \left(\rho_f - 2\rho_f^2 \beta_k \right) \frac{\partial \beta_k}{\partial \tau}.$$

When k = S, $\dfrac{\partial \beta_S}{\partial \tau} = 0$ by assumption. Therefore, $\dfrac{\partial x_f^S}{\partial \tau} = 0$ and $\dfrac{\partial x_h^S}{\partial \tau} = 0$.

When k = N, $\dfrac{\partial \beta_N}{\partial \tau} = \dfrac{-\beta_N \dfrac{\partial Var_{\Phi_N}(\rho_f)}{\partial \tau}}{\left(1 + E_{\Phi_N}(\rho_f)^2 + Var_{\Phi_N}(\rho_f)\right)} < 0$. Therefore, $\dfrac{\partial x_f^N}{\partial \tau} < 0$, and

$\dfrac{\partial x_h^N}{\partial \tau} > (<)0$ as $1 < (>)2\rho_f \beta_N$. From claim 2, $1 < (>)2\rho_f \beta_N$ as the firm's equilibrium effort

is a strategic substitute (complement) to the homeowner. Q.E.D.

Claim 3: In the Citizen suit subgame, the homeowner's equilibrium effort is a strategic

complement (substitute) to the firm as $1 > (<)2\rho_h \beta_C$.

Proof of Claim 3: From claim 1, the homeowner's effort is a strategic complement

(substitute) to the firm as $x_f > (<)\alpha_h x_h$. Substituting $[x_f^C, x_h^C]$, the homeowner's

equilibrium effort is a strategic complement (substitute) to the firm as

$$V_f\left(\rho_h\beta_c(\varpi_h,\alpha_h,\tau)-\left(\rho_h\beta_c(\varpi_h,\alpha_h,\tau)\right)^2\right) > (<)\alpha_h V_h\beta_c\left(\varpi_h,\alpha_h,\tau\right)^2 \text{, or rearranging terms,}$$

as $1 > (<)2\rho_h\beta_c$. $\hspace{4cm}$ Q.E.D.

Proof of Proposition 5:

First, consider the partial derivatives of x_f^k and x_h^k with respect to ϖ_h where $k = S$ or

N. Suppressing functional arguments to ease exposition,

$$\frac{\partial x_f^k}{\partial \varpi_h} = 2V_f\beta_k\frac{\partial \beta_k}{\partial \varpi_h}$$

and

$$\frac{\partial x_h^k}{\partial \varpi_h} = V_f\left[\left(\rho_f\beta_k - \left(\rho_f\beta_k\right)^2\right) + \varpi_h\left(\frac{\left(\rho_f\beta_k\right)^2}{\varpi_h} - \frac{\rho_f\beta_k}{2\varpi_h}\right) + \varpi_h\frac{\partial \beta_k}{\partial \varpi_h}\left(\rho_f - \rho_f^2\beta_k\right)\right].$$

Recall that $\beta_S = \dfrac{E_{\Phi_S}(\rho_f)}{2}$ and $\beta_N = \dfrac{E_{\Phi_N}(\rho_f)}{1+E_{\Phi_N}(\rho_f^2)}$. Both β_S and β_N are independent of ϖ_h

such that $\dfrac{\partial \beta_k}{\partial \varpi_h} = 0$. Therefore, $\dfrac{\partial x_f^k}{\partial \varpi_h} = 0$ and $\dfrac{\partial x_h^k}{\partial \varpi_h} = V_f\dfrac{\rho_f\beta_k}{2} > 0$.

Second, consider the partial derivatives of x_f^C and x_h^C with respect to ϖ_h.

$$\frac{\partial x_f^C}{\partial \varpi_h} = V_f\left[\varpi_h^{-1}\left(\frac{\rho_h\beta_C}{2} - \left(\rho_h\beta_C\right)^2\right) + \frac{\partial \beta_C}{\partial \varpi_h}\left(\rho_h - 2\rho_h^2\beta_C\right)\right]$$

and

$$\frac{\partial x_h^C}{\partial \varpi_h} = V_f\left[\beta_C^2 + 2\varpi_h\beta_C\frac{\partial \beta_C}{\partial \varpi_h}\right].$$

Recall $\beta_c = \dfrac{\sqrt{\varpi_h \alpha_h}}{2}$ such that $\dfrac{\partial \beta_c}{\partial \varpi_h} = \dfrac{\beta_c}{2\varpi_h}$. Substitution implies

$$\frac{\partial x_f^C}{\partial \varpi_h} = V_f \left[\frac{\rho_h \beta_c - 2(\rho_h \beta_c)^2}{\varpi_h} \right] \text{ and } \frac{\partial x_h^C}{\partial \varpi_h} = 2V_f \beta_c^2. \text{ Therefore, } \frac{\partial x_h^C}{\partial \varpi_h} > 0, \text{ while}$$

$$\frac{\partial x_f^C}{\partial \varpi_h} > (<)0 \text{ as } 1 > (<)2\rho_h \beta_c, \text{ or from claim 3, as the homeowner's equilibrium effort is a}$$

strategic complement (substitute) to the firm.   Q.E.D.

Proof of Proposition 6:

First consider the kth subgame where k = S or N. The partial derivatives of x_f^k and x_h^k

with respect to α_h are

$$\frac{\partial x_f^k}{\partial \alpha_h} = 2V_f \beta_k \frac{\partial \beta_k}{\partial \alpha_h}$$

and

$$\frac{\partial x_h^k}{\partial \alpha_h} = V_h \left[\left(\frac{(\rho_f \beta_k)^2}{\alpha_h} - \frac{\rho_f \beta_k}{2\alpha_h} \right) + \frac{\partial \beta_k}{\partial \alpha_h} (\rho_f - \rho_f^2 \beta_k) \right].$$

When k = S, $\dfrac{\partial \beta_S}{\partial \alpha_h} = -\dfrac{\beta_S}{2\alpha_h}$. Substituting and rearranging terms,

$$\frac{\partial x_f^S}{\partial \alpha_h} = -\frac{V_f \beta_S^2}{\alpha_h} < 0 \text{ and } \frac{\partial x_h^S}{\partial \alpha_h} = \frac{V_h}{\alpha_h} \left[2(\rho_f \beta_S)^2 - \rho_f \beta_S \right] > (<)0 \text{ as } 2\rho_f \beta_S > (<)1.$$

Therefore, from claim 2, $\dfrac{\partial x_h^F}{\partial \alpha_h} > (<)0$ as the firm's effort is a strategic substitute

(complement) to the homeowner in the SLAPP subgame.

When k = N, $\dfrac{\partial \beta_N}{\partial \alpha_h} = \dfrac{\beta_N}{2\alpha_h}\xi$ where $\xi = \dfrac{E_{\Phi_N}\left(\rho_f^2\right)-1}{E_{\Phi_N}\left(\rho_f^2\right)+1}$. Substituting and rearranging

terms, $\dfrac{\partial x_f^N}{\partial \alpha_h} = \dfrac{V_f \beta_N^2}{\alpha_h}\xi > (<)0$ as $\xi >(<)$ 0, and

$$\dfrac{\partial x_h^N}{\partial \alpha_h} = \dfrac{V_h}{\alpha_h}\left[\left(\left(\rho_f \beta_N\right)^2 - \dfrac{\rho_f \beta_N}{2}\right)(1-\xi)\right] > (<)0 \text{ as } \left(\rho_f \beta_N\right)^2 - \dfrac{\rho_f \beta_N}{2} > (<)0 \text{ since } 1 > \xi.$$

$\xi >(<)$ 0 as $E_{\Phi_N}\left(\rho_f^2\right) > (<)1$. $\left(\rho_f \beta_N\right)^2 - \dfrac{\rho_f \beta_N}{2} > (<)0$ as $2\rho_f \beta_N > (<)1$, or from claim 2,

as the firm's equilibrium effort is a strategic substitute (complement) to the homeowner.

Now, consider the Citizen suit subgame. The partial derivatives of x_f^C and x_h^C with

respect to α_h are

$$\dfrac{\partial x_f^C}{\partial \alpha_h} = V_f \left[\left(\dfrac{\rho_h \beta_C}{2\alpha_h} - \dfrac{\left(\rho_h \beta_C\right)^2}{\alpha_h}\right) + \dfrac{\partial \beta_C}{\partial \alpha_h}\left(\rho_h - 2\rho_h^2 \beta_C\right)\right]$$

and

$$\dfrac{\partial x_h^C}{\partial \alpha_h} = 2V_h \beta_C \dfrac{\partial \beta_C}{\partial \alpha_h}.$$

Substituting $\dfrac{\partial \beta_c}{\partial \alpha_h} = \dfrac{\beta_c}{2\alpha_h}$, $\dfrac{\partial x_h^C}{\partial \alpha_h} = \dfrac{V_h \beta_c}{\alpha_h} > 0$ and $\dfrac{\partial x_f^C}{\partial \alpha_h} = \dfrac{V_f}{\alpha_h}\left[\rho_h \beta_c - 2(\rho_h \beta_c)^2\right] > (<)0$ as

$1 > (<)2\rho_h \beta_c$, or from claim 3, as the homeowner's equilibrium effort is a strategic

complement (substitute) to the firm. $\hspace{6cm}$ Q.E.D.

Proof of Proposition 7:

$\qquad$ First, note that x_h^C is always positive such that the homeowner's expected payoff is

always positive provided she chooses Sue. Therefore, the set of homeowner's types that

choose Squawk over Sue must also have positive payoffs. This implies an interior solution for

the kth subgame for k = S or N given the homeowner chooses Squawk. Substituting x_f^k and

x_h^k into the firm's expected payoff function for an interior solution where k = S or N yields

$$E\pi_f^k = \int_{v \in R} V_f\left(\rho_f(v)\beta_k - \beta_k^2\right)d\Phi(v,\tau) = V_f\left(E_\Phi\left(\rho_f(v)\right)\beta_k - \beta_k^2\right).$$

$\qquad$ Assume the firm's payoff in the NASH subgame is always strictly greater than the

firm's payoff in the SLAPP subgame. This implies that

$$V_f\left(E_\Phi\left(\rho_f(v)\right)\beta_N - \beta_N^2\right) > V_f\left(E_\Phi\left(\rho_f(v)\right)\beta_S - \beta_S^2\right),$$

or, rearranging terms, that

$$\frac{E_\Phi\left(\rho_f(v)^2\right)}{\left(1 + E_\Phi\left(\rho_f(v)^2\right)\right)^2} > \frac{1}{4}. \qquad\qquad\qquad\qquad (A1)$$

Maximizing the left-hand side of (A1) with respect to $E_\Phi\big(\rho_f(v)^2\big)$ implies that

$$\frac{E_\Phi\big(\rho_f(v)^2\big)}{\big(1+E_\Phi\big(\rho_f(v)^2\big)\big)^2} \le \frac{1}{4}.$$ Therefore, (A1) can never be satisfied and the firm's payoff in the

NASH subgame can never dominate the firm's payoff in the SLAPP subgame.   Q.E.D.

Claim 4: Given the firm's updated beliefs in the kth subgame, if

$$\breve{v}_k = \frac{1}{\alpha_h}\Big(1-\sqrt{1-2\beta_k(\varpi_h,\alpha_h,\tau)}\Big)^2 \text{ and } \hat{v}_k = \frac{1}{\alpha_h}\Big(1+\sqrt{1-2\beta_k(\varpi_h,\alpha_h,\tau)}\Big)^2, \text{ then the}$$

homeowner chooses Squawk when $\breve{v}_k \le \varpi_h \le \hat{v}_k$, and chooses Sue when $0 < \varpi_h < \breve{v}_k$ or

$\varpi_h > \hat{v}_k$.

Proof of Claim 4: Given the firm's updated beliefs in the kth subgame, the homeowner's

expected payoff from choosing Squawk is $V_h\big(1-\rho_f\beta_k(\varpi_h,\alpha_h,\tau)\big)^2$. The homeowner's

expected payoff from choosing Sue is $V_h\big(\rho_h\beta_C(\varpi_h,\alpha_h,\tau)-\beta_C(\varpi_h,\alpha_h,\tau)^2\big)$. Therefore, the

homeowner chooses Squawk (Sue) when

$$V_h\big(1-\rho_f\beta_k(\varpi_h,\alpha_h,\tau)\big)^2 > (<)V_h\big(\rho_h\beta_C(\varpi_h,\alpha_h,\tau)-\beta_C(\varpi_h,\alpha_h,\tau)^2\big). \tag{A2}$$

Substituting $\beta_C(\varpi_h,\alpha_h,\tau) = \frac{\sqrt{\varpi_h\alpha_h}}{2}$ and rearranging terms in (A2), the homeowner

chooses Squawk (Sue) when

$$\Delta_k(\rho_h) = -\frac{1}{2}\rho_h{}^2 + \rho_h - \beta_k(\varpi_h,\alpha_h,\tau) > (<)0. \tag{A3}$$

Notice that (A3) is a quadratic form such that $\Delta_k(\rho_h) = 0$ when

$$\rho_h = 1 \pm \sqrt{1 - 2\beta_k(\varpi_h, \alpha_h, \tau)}, \quad \Delta_k{}'(\rho_h) = 0 \text{ when } \rho_h = 1, \text{ and } \Delta_k{}''(\rho_h) < 0.$$ Assuming an

indifferent homeowner chooses Squawk, this implies that when $\check{v}_k \leq \varpi_h \leq \hat{v}_k$, $\Delta_k(\rho_h) \geq 0$

and the homeowner prefers Squawk. When $\varpi_h < \check{v}_k$ or $\varpi_h > \hat{v}_k$, $\Delta_k(\rho_c) < 0$ and the

homeowner prefers Sue. Finally, each agent's valuation must be positive if an agent is willing

to enter this game, so $\varpi_h > 0$.   Q.E.D.

Proof of Proposition 8:

Recall that a perfect Bayesian equilibrium requires two conditions, sequential

rationality and consistent beliefs (beliefs updated by Bayes rule where possible). Since the

play of the game specified in proposition 8 implies that the firm should never witness a

homeowner choose Squawk, the firm's updated beliefs given Squawk have 0 probability of

being on the equilibrium path. This implies that the firm can not use Bayes rule to update its

beliefs. In this case, consistency requires that the firm's updated beliefs support the

equilibrium. Given propositions 1 and 7, claim 4 implies that for Sue to be sequentially

rational for all homeowner's types $\Delta_k(\rho_h(v)) < 0$ for all v. Recall from the proof of claim 4

that $\Delta_k(\rho_h)$ is maximized when $\rho_h = 1$. Therefore, if $\Delta_k(1) < 0$ given $\beta_k(\varpi_h, \alpha_h, \tau)$, then

$\Delta_k(\rho_h(v)) < 0$ for all v. From (A3), $\Delta_k(1) < 0$ when $\beta_k(\varpi_h, \alpha_h, \tau) > \dfrac{1}{2}$. So, if

$\beta_k(\varpi_h, \alpha_h, \tau) > \dfrac{1}{2}$, all homeowner's types choose Sue, and from proposition 1, strategically

commit a level of effort $x_h{}^C$. The firm responds with a level of effort $x_f{}^C$ given $x_h{}^C$. Q.E.D.

Proof of Proposition 9:

From claim 4, sequential rationality requires that given the firm's updated beliefs the

homeowner chooses Squawk when $\breve{v}_k \le \varpi_h \le \hat{v}_k$, and Sue when $0 < \varpi_h < \breve{v}_k$ or $\varpi_h > \hat{v}_k$.

By Bayes rule, the firm's updated beliefs are

$$\Phi_k(v, \tau) \equiv \begin{cases} 0, & \text{for } \varpi_h < \breve{v}_k \\ \dfrac{G(v, \tau) - G(\breve{v}_k, \tau)}{G(\hat{v}_k, \tau) - G(\breve{v}_k, \tau)}, & \text{for } \breve{v}_k \le \varpi_h \le \hat{v}_k \\ 1, & \text{for } \hat{v}_k < \varpi_h \end{cases} \tag{A4}$$

From claim 4,

$$\breve{v}_k = \frac{1}{\alpha_h}\left(1 - \sqrt{1 - 2\beta_k(\varpi_h, \alpha_h, \tau)}\right)^2 \tag{A5}$$

and

$$\hat{v}_k = \frac{1}{\alpha_h}\left(1 + \sqrt{1 - 2\beta_k(\varpi_h, \alpha_h, \tau)}\right)^2. \tag{A6}$$

From above,

$$\beta_S(\varpi_h, \alpha_h, \tau) = \frac{\int_{\breve{v}_s}^{\hat{v}_s}(v\alpha_h)^{-\frac{1}{2}}d\Phi_S(v, \tau)}{2}, \tag{A7}$$

and

$$\beta_N\left(\varpi_h,\alpha_h,\tau\right)=\frac{\int_{\check{v}_N}^{\hat{v}_N}\left(v\alpha_h\right)^{-\frac{1}{2}}d\Phi_N\left(v,\tau\right)}{1+\int_{\check{v}_N}^{\hat{v}_N}\left(v\alpha_h\right)^{-1}d\Phi_N\left(v,\tau\right)}.$$ (A8)

When the SLAPP subgame is played given the homeowner chooses Squawk, equations (A4),

(A5), (A6) and (A7) determine $\Phi_S(v,\tau)$, $\check{v}_S$, $\hat{v}_S$, and $\beta_S(\varpi_h,\alpha_h,\tau)$ should they exist.

When the NASH subgame is played given the homeowner chooses Squawk, equations (A4),

(A5), (A6) and (A8) determine $\Phi_N(v,\tau)$, $\check{v}_N$, $\hat{v}_N$, and $\beta_N(\varpi_h,\alpha_h,\tau)$ should they exist.

Since these systems of equations are nonlinear and non-monotonic, a unique equilibrium is not

guaranteed.

From proposition 1, if the homeowner chooses Sue, the homeowner strategically

commits a level of effort $x_h{}^c$ and the firm responds by selecting a level of effort $x_f{}^c$. If the

homeowner chooses Squawk and the kth subgame is played given the homeowner chooses

Squawk, proposition 1 implies that the firm chooses a level of effort $x_f{}^k$, and the homeowner

chooses a level of effort $x_h{}^k$.   Q.E.D.

APPENDIX B. RENT DISSIPATION AND EFFICIENCY IN A CONTEST WITH ASYMMETRIC VALUATION[1]

A paper submitted to *Public Choice*

Terrance M. Hurley

Abstract

This paper argues that rent dissipation does not measure all the significant benefits and costs associated with efficiency in a contest with asymmetric valuation. The paper proposes an alternative measure of efficiency defined as the expected proportion of the maximum obtainable benefit captured by the contest, and demonstrates that this alternative measure of efficiency can lead to conclusions that differ significantly from conclusions drawn using rent dissipation. The primary conclusion is that rent dissipation is a potentially biased measure of efficiency in contest with asymmetric valuations.

I. Introduction

Since the seminal work by Tullock (1967, 1980), efficiency in rent-seeking and contest

models has been primarily judged based on rent dissipation where rent dissipation is defined as

the total expenditure of resources by all agents in an effort to capture a rent or prize. With the

exception of Ellingsen (1991), I have found no divergence from this trend. In fact, when

agents value a prize symmetrically, there seems to be little rational to deviate from this

standard. However, when the assumption of symmetric valuation is relaxed as in Hillman and

Riley (1989), Hirshleifer (1989), Suen (1989), Ellingsen (1991), Baik (1994) and Baik and

Shogren (1994), rent dissipation is a potentially biased measure of efficiency.

This paper argues that when agents have asymmetric valuations efficiency may

increase even when rent dissipation increases. The paper also shows that the change in rent

dissipation due to a change in the contest environment generally provides a biased estimate of

the change in efficiency. The logic behind this counter intuitive result is based on the

supposition that efficiency is based on the expected net value of the contest.[2] Given this

supposition, efficiency increases as the probability of success of the agent with highest

valuation of the prize increases holding all other factors constant. If an increase in the

expected benefit of the agent with the highest valuation exceeds the increased cost of effort,

efficiency increases.

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[2]While the distribution of costs and benefits across agents is crucial to social welfare, it is common in the rent seeking

literature to separate questions regarding efficiency from distribution by assuming all costs and benefits can be freely

redistributed to all members of society.

II. Rent Dissipation and Contest Efficiency Defined

Consider an N-agent contest where each agent i expends an observable, irreversible level of effort x_i to increase the probability that she wins a prize.[3] The cost of the ith agent's effort is $C_i(x_i)$. Assume that cost functions posses the standard positive, non-decreasing marginal cost, $C_i'(x_i) > 0$, and $C_i''(x_i) \geq 0$. The ith agent's probability of winning the contest given all agents' investments in effort is $P^i(x_1,...,x_i,...,x_N)$ where $0 \leq P^i(x_1,...,x_i,...,x_N) \leq 1$

and $\sum_{i=1}^{N} P^i(x_1,...,x_i,...,x_N) = 1$. Assume the ith agent's effort increases her probability of

winning at a decreasing rate, $P_{x_i}^i(x_1,...,x_i,...,x_N) > 0$ and $P_{x_i x_i}^i(x_1,...,x_i,...,x_N) < 0$,

implying $P^i(x_1,...,x_i,...,x_N)$ is twice continuously differentiable.[4] If the ith agent wins the contest, the value of prize commensurate in comparable units is G_i. All agents are assumed to have common knowledge about the complete specification of the game.

Rent dissipation is the total cost of effort expended by all agents attempting to capture the prize,

$$R = \sum_{i=1}^{N} C_i(x_i). \tag{B1}$$

As R increases, the total cost of resources expended contesting the prize increases. This has traditionally been interpreted as a decrease in efficiency.

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[3] The contest I consider is a slightly more general, but similar to Baik (1994).

[4] While I am considering imperfectly discriminating contest in this model, the arguments presented here can be extended to a perfectly discriminating contest where the contest success function is discontinuous.

Consider an alternative measure of efficiency defined as the expected proportion of the maximum obtainable benefit captured by the contest. The cost of the contest is the total cost of effort expended by all agents, rent dissipation. The benefit of the contest is the value of the prize to the winner of the contest. Given the N agents' investments in effort, the expected benefit of the contest is $\sum_{i=1}^{N} P^i(x_1,...,x_i,...,x_N)G_i$. The maximum obtainable benefit of the contest is the maximum valuation of the prize. This can occur only if all agents agree to allow the agent with the highest valuation to claim the prize without expending any effort. This result might take place if the distribution mechanism was a competitive market, or second bid Vickery auction as opposed to a contest. Therefore, contest efficiency can be written as the net expected benefit of the contest, the expected benefit minus rent dissipation, divided by the maximum valuation,

$$CE = \frac{\sum_{i=1}^{N} P^i(x_1,...,x_i,...,x_N)G_i - \sum_{i=1}^{N} C_i(x_i)}{Max(G_1,...,G_i,...,G_N)}.$$ (B2)

The maximum value of CE is 1 if $P^i(x_1,...,x_i,...,x_N) = 1$ for the agent with the highest valuation and $\sum_{i=1}^{N} C_i(x_i) = 0$. There is no similar natural lower bound on CE. As CE increases and approaches 1, the contest is capturing a larger expected net benefit and is considered more efficient.

If all agents value the contest the same, $G_i = G$ for all i, and contest efficiency reduces to

$$CE = \frac{G - \sum_{i=1}^{N} C_i(x_i)}{G} = 1 - \frac{R}{G}. \tag{B3}$$

In this case, rent dissipation is inversely related to contest efficiency, and the two measures are essentially equivalent.[5]

III. Rent Dissipation Vs. Contest Efficiency

It is common in the literature for efficiency comparisons to be made between alternative institutional structures. One common comparison is between a Cournot-Nash simultaneous move contest and a Stackelberg leadership contest as in Dixit (1987) and Baik and Shogren (1992). Another comparison, Baik and Shogren (1994), considers efficiency across contest with alternative player reimbursement schemes. This research is important because it provides insights into what types of policies may increase the efficiency of a contest. This section argues that rent dissipation and contest efficiency may lead to different conclusions regarding which institutions are more efficient when agents have asymmetric valuations. Contest efficiency provides a better measure of efficiency because it captures all relevant costs and benefits of a contest.

As a motivating example, consider a contest under two alternative institutional structures. The first institutional structure is such that each agent pays the full amount of her effort. The second institutional structure is such that the agent with the lower valuation must

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[5] This equivalency holds as long as we do not consider the relationship between efficiency and G when talking about equilibrium behavior such that rent dissipation is a function of G. This will become more apparent in my discussion below.

reimburse a portion of her opponent's effort given her opponent wins the contest [see Baik

and Shogren (1994)]. Without loss of generality, assume the agent with the highest valuation

is agent 1. Also assume $G_1 = 400$, $G_2 = 100$, $P^1(x_1, x_2) = \dfrac{x_1}{x_1 + \sigma x_2}$, $P^2(x_1, x_2) = \dfrac{\sigma x_2}{x_1 + \sigma x_2}$

and $C_i(x_i) = x_i$ where σ is an ability parameter as defined in Baik (1994) and is assumed to

be 0.5. Following Baik and Shogren (1994), the proportion of agent 1's effort that agent 2

must reimburse given agent 1 wins the contest is β. Under the first institution, let $\beta = 0$. In

this case, agent 1 and 2's equilibrium efforts are 39.506 and 9.877 which imply rent

dissipation is 49.383 and contest efficiency is 72.7%. Under the second institution assume $\beta =$

0.5. Now agent 1 and 2's equilibrium efforts are 54.563 and 8.729 which imply rent

dissipation is 63.292 and contest efficiency is 73.8%. Notice that rent dissipation suggest that

the first institution is more efficient than the second institution because rent dissipation is

lower, 49.383 < 63.292, while contest efficiency suggest the second institution is more

efficient than the first institution, 73.8% > 72.7%. Therefore, which institution leads to a

more efficient contest?

The second institution leads to a more efficient contest because, while both contest

efficiency and rent dissipation take into account the additional cost of effort, only contest

efficiency takes into account how this additional effort influences the probability of success of

the agent with the highest valuation. Therefore, the increase in the probability of success of

agent 1 due to an increase in her effort is a benefit, and in this case, is enough of a benefit to

outweigh the additional rent dissipated. The second institution is more efficient because it

leads to the capture of a higher expected net benefit than the first institution.

Consider two alternative equilibrium levels of effort, $(x_1',...,x_N')$ and $(x_1'',...,x_N'')$.

Assume that the difference in rent dissipation between $(x_1',...,x_N')$ and $(x_1'',...,x_N'')$ is positive such that

$$\Delta R = \sum_{j=1}^{N}\left(C_j(x_j') - C_j(x_j'')\right) > 0.$$ (B4)

The difference in contest efficiency between $(x_1',...,x_N')$ and $(x_1'',...,x_N'')$ is

$$\Delta CE = \frac{\sum_{j=1}^{N}\left(P^j(x_1',...,x_N') - P^j(x_1'',...,x_N'')\right)G_j - \Delta R}{Max(G_1,...,G_N)}.$$ (B5)

The numerator of (B5) represents the difference in the expected net benefit of the two alternative equilibria. The first term in the numerator of (B5) represents the difference in the expected benefits of the two alternative equilibria, while the second term represents the difference in rent dissipation.

If $\sum_{j=1}^{N}\left(P^j(x_1',...,x_N') - P^j(x_1'',...,x_N'')\right)G_j > \Delta R$, then $\Delta CE > 0$. While rent dissipation implies that the second equilibrium is more efficient, contest efficiency implies that the first equilibrium is more efficient. This result is summarized in Proposition 1.

Proposition 1: Given two alternative equilibrium levels of effort, contest efficiency is greater for the equilibrium with the higher rent dissipation when the difference in the expected benefit of the alternative equilibria is greater than the difference in rent dissipation.

Proposition 1 implies that even if more resources are spent in a contest, efficiency may be higher if the increased resource expenditures lead to increases probabilities that agents with higher valuations win the contest. The crux of the argument is that when valuations are asymmetric society has a stake in who wins the contest. While increases in resource expenditures tend to reduce the value of a contest to society, if these increased expenditures improve the odds that a more desirable state occurs, then the benefit of the expenditures may exceed the cost and increase efficiency.

IV. Rent Dissipation, Contest Efficiency, and Comparative Statics

Section III established that for identical contest success functions and benefits, rent dissipation and contest efficiency can provide different conclusions regarding efficiency when considering alternative equilibria. This section considers the difference between rent dissipation and contest efficiency when evaluating comparative static effects, and demonstrates that even when both measures lead to the same conclusion rent dissipation is a biased measure of the change in contest efficiency.

Assume $N = 2$, $G_1 = \alpha G$ and $G_2 = G$. In this case, α scales agent 1's valuation relative to agent 2's valuation without loss of generality. Contest efficiency is then defined as

$$CE = \frac{P(x_1, x_2)\alpha G + (1 - P(x_1, x_2))G - C_1(x_1) - C_2(x_2)}{Max(\alpha, 1)G}.$$

(B7)

If $\alpha >(<) 1$, then agent 1's valuation exceeds (is less than) agent 2's valuation and the denominator of CE is αG (G).

As an example, consider the relationships between agents' relative valuations, rent

dissipation and contest efficiency. The partial derivative of rent dissipation with respect to α

is

$$\frac{\partial R}{\partial \alpha} = C_1' x_{1_\alpha} + C_2' x_{2_\alpha} , \tag{B8}$$

where $x_{1_\alpha} = \dfrac{\partial x_1}{\partial \alpha}$ and $x_{2_\alpha} = \dfrac{\partial x_2}{\partial \alpha}$. The partial derivative of contest efficiency with respect to

α is

$$\frac{\partial CE}{\partial \alpha} = \frac{\left[\dfrac{\partial \pi_1}{\partial x_1} x_{1_\alpha} + \dfrac{\partial \pi_2}{\partial x_2} x_{2_\alpha} + P_{x_2} \alpha G x_{2_\alpha} - P_{x_1} G x_{1_\alpha} \right]}{Max(\alpha,1)G}$$

$$+ \frac{\left\{ Max(\alpha,1)PG - \dfrac{\partial Max(\alpha,1)}{\partial \alpha}(\Lambda) \right\}}{Max(\alpha,1)^2 G} \tag{B9}$$

where $\dfrac{\partial \pi_1}{\partial x_1} = P_{x_1} \alpha G - C_1'$, $\dfrac{\partial \pi_2}{\partial x_2} = -P_{x_2} G - C_2'$, and

$$\Lambda = P(x_1, x_2)\alpha G + (1 - P(x_1, x_2))G - C_1(x_1) - C_2(x_2).$$

The interpretation of (B8) is straight forward and represents the change in rent

dissipation due to an increase in agent 1's relative valuation. If both agents' equilibrium

efforts increase (decrease), then rent dissipation unambiguously increases (decreases). If one

agent's effort increases while the other agent's effort decreases, then rent dissipation may

increase or decrease depending on each agent's marginal cost of effort and the magnitude of

each agent's equilibrium change in effort.

The right-hand-side of (B9) is grouped into two categories. The first expression in brackets represents the indirect effect of a change in α, while the second expression in curly brackets represents the direct effect of a change in α. The indirect effect measures the change in the net expected benefit due to the change in the equilibrium levels of effort associated with an increase in α. The direct effect measures the change in the expected net benefit and the maximum obtainable benefit directly associated with an increase in α.

The indirect effect in the first expression on the right-hand-side of (B9) can be broken down into indirect-own (IO) effect and indirect-cross (IC) effect. As agents alter their equilibrium levels of effort, this change influences an agent's own expected benefit and cost of the contest. The first and second terms in brackets capture this IO effect for agent 1 and agent 2. As an agent alters her equilibrium level of effort, this not only affects her own expected benefit and cost, but it also affects her opponent's expected benefit by reducing the probability of success of her opponent. The third and fourth terms in the square brackets capture the IC effect. The third term in square brackets represents the marginal decrease in agent 1's expected payoff due to an increase in agent 2's equilibrium level of effort, while the fourth term in square brackets represents the marginal decrease in agent 2's expected payoff due to an increase in agent 1's equilibrium level of effort.

The first term in curly brackets on the right-hand-side of (B9) represents the direct effect of a change in α on the expected net benefit (NB) of the contest, while the second term in curly brackets represents the direct effect of a change in α on the maximum obtainable benefit (MOB). Therefore, the net direct effect (ND) is equal to NB effect minus the MOB

effect, ND = NB - MOB. The MOB effect is subtracted from the NB effect because we are

considering a change in the ratio. As α increases holding equilibrium levels of effort constant,

the NB effect increases because the value of agent 1's prize increases. As α increases the

MOB effect is non-decreasing. If $\alpha < 1$, then $\dfrac{\partial Max(\alpha,1)}{\partial \alpha} = 0$. The only direct effect is due

to an increase in the NB effect which tends to increase efficiency as α increases. If $\alpha \geq 1$, then

$\dfrac{\partial Max(\alpha,1)}{\partial \alpha} = 1$. In this case, the ND effect is positive (negative) as the percentage change in

the NB effect is greater (less) than the percentage change in the MOB effect,

$$\dfrac{\dfrac{\partial \Lambda}{\partial \alpha}}{\Lambda} > (<) \dfrac{\dfrac{\partial Max(\alpha,1)}{\partial \alpha}}{Max(\alpha,1)}.$$

Consider a contest where both agents choose their equilibrium levels of effort

simultaneously. In this case, agent 1's and agent 2's expected payoffs are

$\pi_1 = P(x_1,x_2)\alpha G - C_1(x_1)$ and $\pi_2 = \left(1 - P(x_1,x_2)\right)G - C_2(x_2)$. The first-order conditions

for agents 1 and 2 are $\dfrac{\partial \pi_1}{\partial x_1} = P_1\alpha G - C_1' = 0$, and $\dfrac{\partial \pi_2}{\partial x_2} = -P_2 G - C_2' = 0$. Assuming the

equilibrium exists and is an interior solution, the equilibrium levels of effort satisfy both first-

order conditions.[6]

Consider how an increase in α influences contest efficiency in this Cournot-Nash

contest. Substituting the first-order conditions into (9) yields

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[6] For a more detailed discussion of this type of equilibrium, see Baik (1994).

$$\frac{\partial CE}{\partial \alpha} = \frac{-\left[\frac{1}{\alpha}C_1{}'x_{1_\alpha} + \alpha C_2{}'x_{2_\alpha}\right]}{Max(\alpha,1)G} + \frac{\left\{Max(\alpha,1)PG - \frac{\partial Max(\alpha,1)}{\partial \alpha}(\Lambda)\right\}}{Max(\alpha,1)^2 G},$$ (B10)

while the same substitution into (B8) has no effect on the change in rent dissipation. This substitution allows us to eliminate the IO effect in (B10), and to transform the IC effect in the first term on the right-hand-side of (B10) such that it resembles the change in rent dissipation in (B8).

Rewriting equation (B10) as

$$\frac{\partial CE}{\partial \alpha} = \frac{-\left[\frac{\partial R}{\partial \alpha}\right]}{Max(\alpha,1)G} + \frac{\left[\left(1-\frac{1}{\alpha}\right)C_1{}'x_{1_\alpha} + (1-\alpha)C_2{}'x_{2_\alpha}\right]}{Max(\alpha,1)G}$$
$$+ \frac{\left\{Max(\alpha,1)PG - \frac{\partial Max(\alpha,1)}{\partial \alpha}(\Lambda)\right\}}{Max(\alpha,1)^2 G}$$ (B11)

suggest two sources of bias. The first term on the right-hand-side of (B11) is the change in contest efficiency due to a change in rent dissipation. The second term is the first source of bias and is associated with the IC effect. The third term is the second source of bias and is associated with the ND effect.

The direction of the IC effect bias depends on the relative size of the agents' marginal costs, valuations and changes in equilibrium level of effort. When $\alpha <(>) 1$, increases in agent 1's equilibrium level effort lead to a negative (positive) bias, while increases in agent 2's equilibrium level of effort lead to positive (negative) bias. When $\alpha = 1$, the IC effect bias is 0. The larger the magnitude of an agent's marginal cost or change in equilibrium effort, the greater the IC effect bias associated with that agent's increase in equilibrium effort.

The direction of the ND effect bias depends on the change in the net benefit and the maximum obtainable benefit directly associated with an increase in α. If $\alpha < 1$, the maximum obtainable benefit does not change and the ND effect bias is positive. If $\alpha \geq 1$, then the ND effect bias is positive (negative) as the percentage change in the NB effect is greater (less) than the percentage change in the MOB effect. This result is summarized in Proposition 2.

Proposition 2: The change in rent dissipation due to a change in agent 1's relative valuation is a biased measure of the change in contest efficiency in a Cournot-Nash simultaneous move contest.

While the net bias is theoretically indeterminate in the general model presented above, once more structure is assumed, the direction of bias is straightforward to measure. Are the biases significant enough in more common specifications of the model to warrant a change to the more complex measure of efficiency? Figure B1 provides the answer for a commonly used specification of a contest where $P(x_1, x_2) = \dfrac{x_1}{x_1 + x_2}$ and $C_i(x_i) = x_i$ for i = 1,2.

Assuming G = 1, let α vary from 0 to 3.

As α increases from arbitrarily close to 0 to 1, the ND effect bias increases from

approximately 0 to 0.5. The strong positive bias as α approaches 1 is due to the increase in

the net benefit directly associated with the increase in α. Once α becomes arbitrarily greater

than 1, the MOB effect bias becomes negative and offsets the NB effect bias. This leads to

the discontinuous drop in the ND effect bias which approaches 0 as α approaches 1 from

above. As α increases from arbitrarily close to 1 to 3, the positive NB effect bias is greater

than the negative MOB effect bias. This leads to a positive ND effect bias over this range.

As α increases from arbitrarily close to 0 to 3, the IC effect bias increases at a
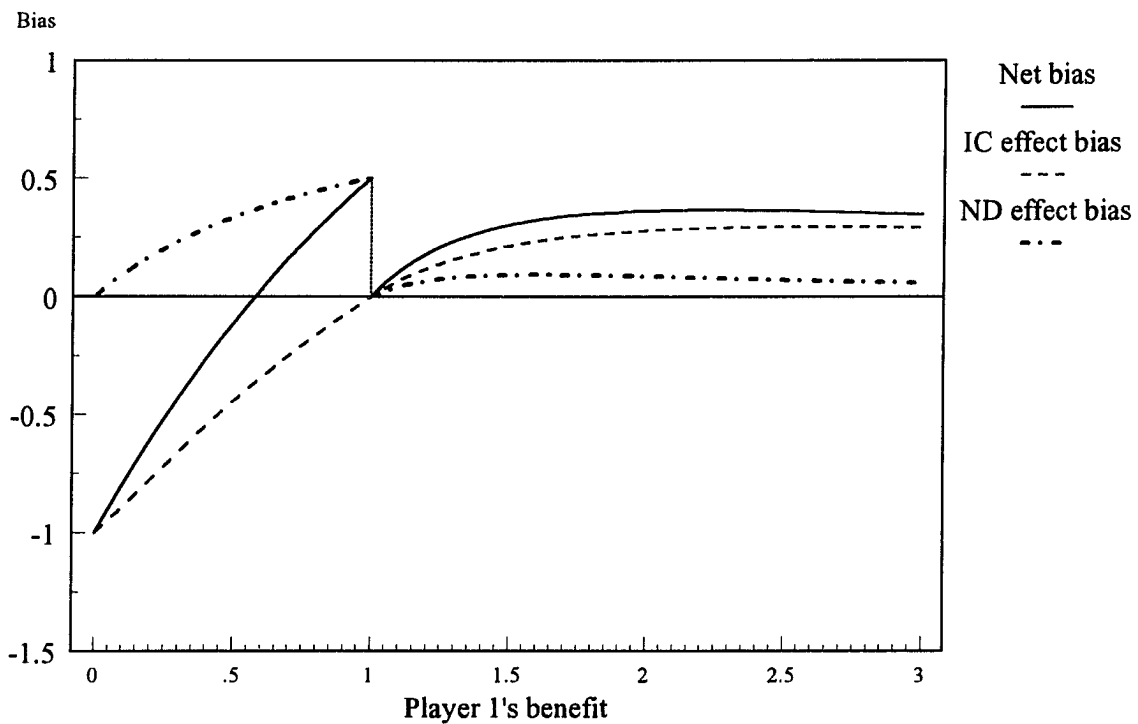
Figure B1: Net bias, IC effect bias and ND bias given Player 1's benefit

decreasing rate, and eventually begins to decrease. The IC effect bias is negative up to $\alpha = 1$. At $\alpha = 1$, the IC effect bias is 0. For $\alpha > 1$, the IC effect bias is positive. When $\alpha < 1$, rent dissipation does not account for the additional cost that an increase in agent 1's equilibrium level of effort imposes by reducing the probability that agent 2, the agent with the highest valuation, wins the contest. This causes the IC effect bias to be negative. When $\alpha = 1$, the change in rent dissipation is equivalent to the change in the IC effect bias because both agents have the same valuation. Therefore, the indirect change in probabilities associated with the change in agents' equilibrium levels of effort has no effect on the benefit of the contest. When $\alpha > 1$, rent dissipation does not account for the additional benefit that an increase in agent 1's equilibrium level of effort imposes by reducing the probability that agent 2, the agent with the lowest valuation, wins the contest. This causes the IC effect bias to be positive.

The Net bias is increasing for $0 < \alpha < 1$. The Net bias becomes 0 around $\alpha = 0.5$ as the positive ND effect bias exactly offsets the negative IC effect bias. At $\alpha = 1$, the Net bias discontinuously jumps and approaches 0 as α approaches 1 from above. For $1 < \alpha < 3$, the Net bias is positive since both the ND and IC effect biases are positive. In this range the Net bias is at first increasing, but then begins to decrease as both the ND and IC effect biases start to decrease.

In Figure B1, the Net bias is 0 at only one point in the range. Given the bias does not generally disappear, is the Net bias significant enough for rent dissipation and contest efficiency to yield contradictory results? The answer is provided in Figure B2 which suggest contradictory results may exist.

In both regions I and II, as agents' valuations diverge (as α approaches 0 in region I,

and as α approaches 3 in region II), contest efficiency is at first decreasing, but then increases.

However, as agents' valuations become more diverse, rent dissipation is decreasing in region I

and increasing in region II. As α is close to 1 and decreases in region I, rent dissipation

indicates that efficiency is increasing, while contest efficiency indicates that efficiency is

decreasing. This contradictory result is attributable to the large positive ND effect bias as α

approaches 1 from below. As α increases in region II approaching 3, rent dissipation
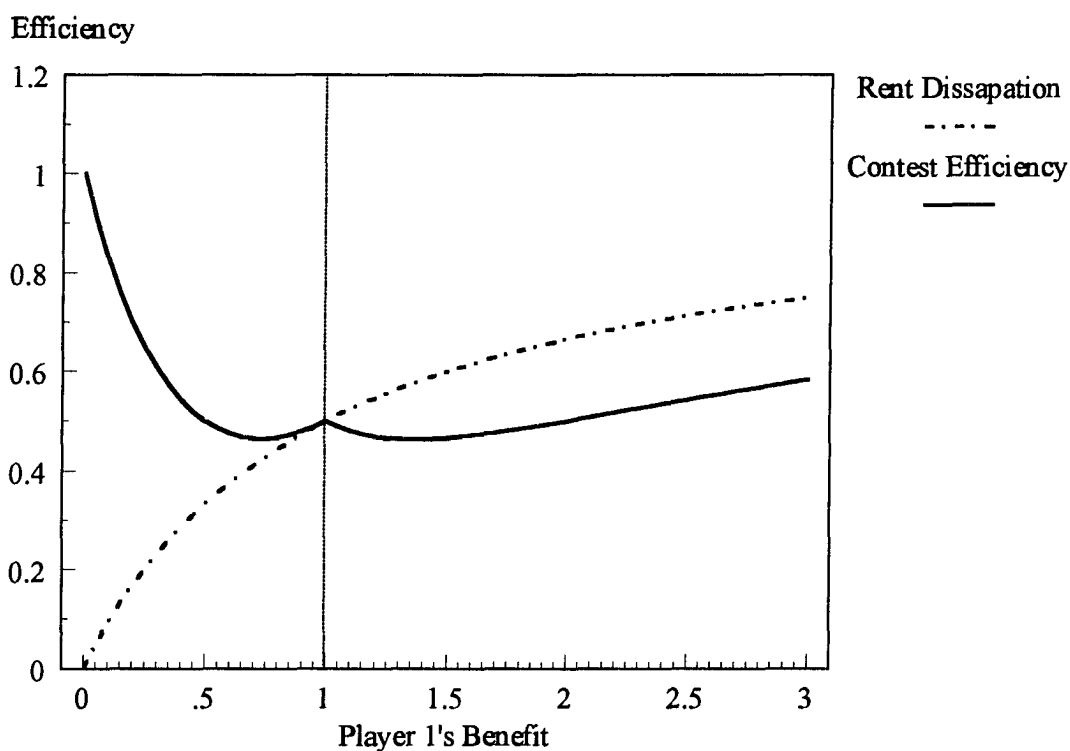
Efficiency

Figure B2: Rent dissipation and Contest efficiency given Player 1's benefit

indicates that efficiency is decreasing, while contest efficiency indicates that efficiency is increasing. This contradictory result is attributable to a combination of the positive ND and IC effect biases. Therefore, even with one of the simplest forms of a contest model with asymmetric valuation, the bias associated with the rent dissipation as a measure of contest efficiency can be significant.

V. Conclusions

The primary purpose of this paper is to propose an alternative measure of efficiency in a contest with asymmetric valuation. Contest efficiency is defined as the proportion of the maximum obtainable benefit captured by a contest, and is argued to be a better measure of efficiency than rent dissipation because contest efficiency accounts for the influence of effort on the probability that the agents with the higher valuations win the contest. The two measures can provide significantly different results whether comparing two alternative equilibria or comparative static changes in the proportion of one agent's benefit relative to her opponent assuming Cournot-Nash behavior.

While the bias of rent dissipation as a measure of contest efficiency is only considered for a change in the relative valuation, the extension to alternative exogenous parameters that might be incorporated into the model, such as ability parameters, is straight forward, and does not significantly alter the results. Also, the analysis is confined to Cournot-Nash behavior for this presentation, but the extensions to Stackelberg type equilibria are straight forward and lead to similar if not more striking conclusions. Hillman and Riley (1989) present a model with transfers such that the success of one agent comes at a cost to all other agents. This is easily incorporated into contest efficiency by redefining the maximum obtainable benefit as the

maximum net value of the contest. While the analysis here does not explicitly investigate perfectly discriminating contest success functions, the sources of bias remain in mixed strategy equilibria where there is always a positive probability that an agent with a lower valuation wins the contest.

Admittedly, contest efficiency is generally a more complex and less tractable measure of efficiency. However, rent dissipation fails to account for a number of costs and benefits captured by contest efficiency. These costs and benefits can significantly alter the conclusions that are drawn. However, if one can determine that the direct and indirect-cross effects are small or nonexistent, then the change in rent dissipation may be a reasonable measure of efficiency. Which measure is used must be judged within the context of any given model, and should attempt to account for all significant costs and benefits.

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APPENDIX C. EXPERIMENTAL INSTRUCTION , EXAMPLE ROUND STRATEGY SHEETS, EXAMPLE ROUND EARNINGS SHEETS, AND FIGURES 1 AND 2

Instructions and Example Round Strategy and Earnings Sheets for Sessions 2 and 3

This is an experiment in group decision making that should take between 2 and 2 1/2 hours to complete. At the end of the experiment, you will be paid for your participation in cash. Different subjects may earn different amounts. What you earn depends partly on your decisions, partly on the decisions of others, and partly on chance. You will find it helpful to refer to **Figures 1 and 2**, your **Strategy Sheets**, your **Example Round Strategy Sheet** and your **Example Round Earnings Sheet** as you read these instructions. After you read these instructions, please complete the quiz. When all subjects have completed the quiz, the answers will be read out loud and any questions will be answered. **Please do not talk to or try to communicate with any other participants during this experiment. If you have a question during the experiment, please raise your hand and an experimenter will help you. If you fail to follow these instructions, you will be asked to leave and forfeit any moneys earned.**

1. **AN OVERVIEW:** During the experiment, you participate in five rounds. In each round, you play five games against randomly selected players. In each game, you receive tokens based on the decisions that you and the randomly selected player make. The first round is a practice round to help you learn the game. In the final four rounds, each token you earn is worth $0.01. You will also earn up to $1.00 a round

for correctly anticipating the randomly selected players' responses, and a $10.00 participation fee.

2. **THE PLAYERS:** There are fifteen players randomly assigned to one of three types. Your type is shown at the top your **Strategy Sheets.**

a) There are five A1-type players, which are referred to as A1s.

b) There are five A2-type players, which are referred to as A2s.

c) There are five B-type players, which are referred to as Bs.

3. **THE GAME (Figures 1 and 2 provide a visual summary of the game):**

a) Player Matches for each game:

i) A1 plays a B.

ii) A2 plays a B.

iii) B plays an A1 and an A2 at the same time.

b) Payoffs (in tokens):

i) A1's payoffs are the first numbers in parentheses in **Figure 1.**

ii) A2's payoffs are the first numbers in parentheses in **Figure 2.**

iii) B's payoffs are the second numbers in parentheses in **Figures 1 and 2.**

c) Game Play: A1 and A2 may choose R or L. If A1 and/or A2 choose R, B may choose U, M or D.

i) When A1 chooses L, A1 earns 60 and B earns 45.

ii) When A2 chooses L, A2 earns 105 and B earns 50.

iii) When A1 chooses R, and

a)   B chooses U, A1 earns 100 and B earns 50.

b)   B chooses M, A1 earns 50 and B earns 40.

c)   B chooses D, A1 earns 0 and B earns 10.

iv)   When A2 chooses R, and

a)   B chooses U, A2 earns 100 and B earns 0.

b)   B chooses M, A2 earns 50 and B earns 30.

c)   B chooses D, A2 earns 0 and B earns 40.

4.   THE EXPERIMENT PROCEEDS AS FOLLOWS:

a)   There are five rounds in the experiment. The first round, **Round 1**, is a practice round.

b)   Round Play:

i)   A round consists of five games.

ii)   Before each round you will complete a two part **Strategy Sheet**.

a)   **Part I asks you to anticipate how the randomly selected players** will play the five games. For example, on your **Example Strategy Sheet,**

3 is circled in (i),

5 is circled in (ii),

1 is circled in (iii) and

4 is circled in (iv).

This implies that you think 3 of the randomly selected A1s will choose R, and 2 will choose L.

You think 5 of the randomly selected A2s will choose R and none will choose L.

You think 1 of the randomly selected Bs will choose U, 4 will choose M and none will choose D.

Each time you respond correctly, you earn \$0.25.

b)   **Part II** asks you to indicate how you will play each of the five games.

     (1)   If you are an A1 or A2, you must choose between R or L for each of the five games. You can pick either R or L for all five games, or any combination of R and L. For example, on your **Example Strategy Sheet**,

         R is circled for **Game 1**,

         R is circled for **Game 2**,

         L is circled for **Game 3**,

         L is circled for **Game 4** and

         R is circled for **Game 5.**

     This implies that you choose to play R for games 1, 2 and 5, and L for games 3, and 4.

     (2)   If you are a B, you must choose how you will play each game provided A1 and /or A2 choose R. You can pick either U, M or D for all five games, or any combination of U, M and D. For example, on your **Example**

Strategy Sheet,

U is circled for **Game 1,**

D is circled for **Game 2,**

M is circled for **Game 3,**

U is circled for **Game 4 and**

D is circled for **Game 5.**

This implies that if A1 and/or A2 choose R you choose

to play U for games 1 and 4, M for game 3, and D for

games 2 and 5.

iii) Once everyone has completed their **Strategy Sheets**, the sheets are

collected, and the match-ups are determined.

a) For each game a different B is randomly selected and his or her

choice is recorded on the A1s' and A2s' **Round Earnings**

Sheet. For example, if you are an A1 or A2 and

the first (randomly selected) B chose U,

the second (randomly selected) B chose M,

the third (randomly selected) B chose M,

the fourth (randomly selected) B chose D and

the fifth (randomly selected) B chose D,

then, on your **Example Round Earnings Sheet,**

U is circled for Game 1,

M is circled for Game 2,

M is circled for Game 3,

D is circled for Game 4 and

D is circled for Game 5.

b) For each game a different A1 is randomly selected and his or her choice is recorded on the Bs' **Round Earnings Sheet**. For example, if you are a B and

the first (randomly selected) A1 chose R,

the second (randomly selected) A1 chose R,

the third (randomly selected) A1 chose R,

the fourth (randomly selected) A1 chose L and

the fifth (randomly selected) A1 chose L,

then, on your **Example Round Earnings Sheet,**

R is circled for Game 1,

R is circled for Game 2,

R is circled for Game 3,

L is circled for Game 4 and

L is circled for Game 5.

c) For each game a different A2 is randomly selected and his or her choice is recorded on the Bs' **Round Earnings Sheet**. For example, if you are a B and

the first (randomly selected) A2 chose L,

the second (randomly selected) A2 chose R,

the third (randomly selected) A2 chose R,

the fourth (randomly selected) A2 chose R and

the fifth (randomly selected) A2 chose L,

then, on your **Example Round Earnings Sheet,**

L is circled for Game 1,

R is circled for Game 2,

R is circled for Game 3,

R is circled for Game 4 and

L is circled for Game 5.

iv)   After the match-ups are determined, the results are recorded and returned to you on your **Round Earnings Sheet. Please carefully review this sheet before completing your next Strategy Sheet.**

c)   Your total earnings for a round is recorded at the bottom of your **Round Earnings Sheet.** For example, if you are an A1, A2 or B you would have earned $3.20, $4.10, or $4.10 for the example round.

i)   You earn $0.25 each time you correctly anticipate the randomly selected players' responses. For example, on your **Example Round Earnings Sheet,** you would have earned a total of $0.50.

$0.25 for correctly anticipating the number of A1s who chose R.

$0.00 for incorrectly anticipating the number of A2s who chose R.

$0.25 for correctly anticipating the number of Bs who

chose U.

$0.00 for incorrectly anticipating the number of Bs who

chose M.

ii)   In rounds 2 through 5, you also receive $0.01 for each token you earn

in the five games. For example, if you are an A1, A2 or B player you

would multiply 270, 360 or 360 by $0.01 to determine your earnings

for the five games in the example round.

5.   After the fifth round is completed, please wait for further instructions.

QUIZ

1.   If A1 chooses L, and A2 chooses L,

   a)   what is A1's payoff?

   b)   what is A2's payoff?

   c)   what is B's payoff from playing A1?

   d)   what is B's payoff from playing A2?

   e)   what is B's total payoff?

2.   If A1 chooses R, A2 chooses L, and B chooses D,

   a)   what is A1's payoff?

   b)   what is A2's payoff?

   c)   what is B's payoff from playing A1?

   d)   what is B's payoff from playing A2?

   e)   what is B's total payoff?

3.   If 2 of the randomly selected A1s choose R and 3 choose L, how much would you have earned if you had circled 4 in **Part I (i)** of your **Strategy Sheet**?

4.   If 5 of the randomly selected A2s choose R and none choose L, how much would you have earned if you had circled 5 in **Part I (ii)** of your **Strategy Sheet**?

5.   If 4 of the randomly selected Bs choose U, none choose M and 1 chooses D, how much would you have earned if you had circled 4 in **Part I (iii)** and 0 in **Part I (iv)** of your **Strategy Sheet**?

6.   What would your total earnings have been for correctly anticipating the other players' responses in questions 3, 4 and 5?

7.   How much money do you earn for a token

   a)   in Round 1?

   b)   in Rounds 2, 3, 4 and 5?

A1-type player

Example Round Strategy Sheet

Part I: Please indicate how you anticipate the other players will play the five games by completing the statements below. Complete statements (i) through (iv) by circling the appropriate numbers. **Please circle only one number. You earn $0.25 for each correct response.**

(i)   I think the (randomly selected) A1s will choose R in [0   1   2   ③   4   5] of the five games.

(ii)   I think the (randomly selected) A2s will choose R in [0   1   2   3   4   ⑤] of the five games.

(iii)   I think the (randomly selected) Bs will choose U in [0   ①   2   3   4   5] of the five games.

(iv)   I think the (randomly selected) Bs will choose M in [0   1   2   3   ④   5] of the five games. **Note that the sum of your responses in statements 3 and 4 should not exceed 5.**

Part II: Please indicate how you will play each of the five games in this round by circling the appropriate letter below. **Please circle only one letter for each game.**

1) For **Game 1**, I choose   Ⓡ   L.

2) For **Game 2**, I choose   Ⓡ   L.

3) For **Game 3**, I choose   R.   Ⓛ

4) For **Game 4**, I choose   R.   Ⓛ

5) For **Game 5**, I choose   Ⓡ   L.

A1-type player

<center>**Example Round Earnings Sheet**</center>

Game Results			
Game	B's Choices	Your Choices	Your Payoff
1	Ⓤ M D	Ⓡ L	100
2	U Ⓜ D	Ⓡ L	50
3	U Ⓜ D	R Ⓛ	60
4	U M Ⓓ	R Ⓛ	60
5	U M Ⓓ	Ⓡ L	0
		Your earnings for the five games:	270

Earnings from Correctly Anticipating Players' Responses		
(i) Number of times you thought the A1s would choose R: 0 1 2 ③ 4 5	Number of times the A1s actually chose R: 0 1 2 ③ 4 5	Ⓢ0.25Ⓢ $0.00
(ii) Number of times you thought the A2s would choose R: 0 1 2 3 4 ⑤	Number of times the A2s actually chose R: 0 1 2 ③ 4 5	$0.25 Ⓢ0.00Ⓢ
(iii) Number of times you thought the Bs would choose U: 0 ① 2 3 4 5	Number of times the Bs actually chose U: 0 ① 2 3 4 5	Ⓢ0.25Ⓢ $0.00
(iv) Number of times you thought the Bs would choose M: 0 1 2 3 ④ 5	Number of times the Bs actually chose M: 0 1 ② 3 4 5	$0.25 Ⓢ0.00Ⓢ
	Total Earnings:	$0.50

Total Earnings for the Round: __270__ X $0.01 + __$0.50__ = __$3.20__

A2-type player

Example Round Strategy Sheet

Part I: Please indicate how you anticipate the other players will play the five games by completing the statements below. Complete statements (i) through (iv) by circling the appropriate numbers. **Please circle only one number. You earn $0.25 for each correct response.**

(i)   I think the (randomly selected) A1s will choose R in [0   1   2   ③   4   5] of the five games.

(ii)   I think the (randomly selected) A2s will choose R in [0   1   2   3   4   ⑤] of the five games.

(iii)   I think the (randomly selected) Bs will choose U in [0   ①   2   3   4   5] of the five games.

(iv)   I think the (randomly selected) Bs will choose M in [0   1   2   3   ④   5] of the five games. **Note that the sum of your responses in statements 3 and 4 should not exceed 5.**

Part II: Please indicate how you will play each of the five games in this round by circling the appropriate letter below. **Please circle only one letter for each game.**

1) For **Game 1**, I choose   ⓡ   L.
2) For **Game 2**, I choose   ⓡ   L.
3) For **Game 3**, I choose   R.   ⓛ
4) For **Game 4**, I choose   R.   ⓛ
5) For **Game 5**, I choose   ⓡ   L.

A2-type player

Example Round Earnings Sheet

Game Results			
Game	B's Choices	Your Choices	Your Payoff
1	(U) M D	(R) L	100
2	U (M) D	(R) L	50
3	U (M) D	R (L)	105
4	U M (D)	R (L)	105
5	U M (D)	(R) L	0
		Your earnings for the five games:	360

Earnings from Correctly Anticipating Players' Responses		
(i) Number of times you thought the A1s would choose R: 0 1 2 (3) 4 5	Number of times the A1s actually chose R: 0 1 2 (3) 4 5	($0.25) $0.00
(ii) Number of times you thought the A2s would choose R: 0 1 2 3 4 (5)	Number of times the A2s actually chose R: 0 1 2 (3) 4 5	$0.25 ($0.00)
(iii) Number of times you thought the Bs would choose U: 0 (1) 2 3 4 5	Number of times the Bs actually chose U: 0 (1) 2 3 4 5	($0.25) $0.00
(iv) Number of times you thought the Bs would choose M: 0 1 2 3 (4) 5	Number of times the Bs actually chose M: 0 1 (2) 3 4 5	$0.25 ($0.00)
	Total Earnings:	$0.50

Total Earnings for the Round: ____360____ X $0.01 + ___$0.50___ = ___$4.10___

B-type player

Example Round Strategy Sheet

Part I: Please indicate how you anticipate the other players will play the five games by completing the statements below. Complete statements (i) through (iv) by circling the appropriate numbers. **Please circle only one number. You earn $0.25 for each correct response.**

(i)   I think the (randomly selected) A1s will choose R in [0   1   2   ③   4   5] of the five games.

(ii)   I think the (randomly selected) A2s will choose R in [0   1   2   3   4   ⑤] of the five games.

(iii)   I think the (randomly selected) Bs will choose U in [0   ①   2   3   4   5] of the five games.

(iv)   I think the (randomly selected) Bs will choose M in [0   1   2   3   ④   5] of the five games. **Note that the sum of your responses in statements 3 and 4 should not exceed 5.**

Part II: Please indicate how you will play each of the five games in this round by circling the appropriate letter below. **Please circle only one letter for each game.**

1) For **Game 1**, if A1 and/or A2 choose R, I choose   Ⓤ   M.   D.

2) For **Game 2**, if A1 and/or A2 choose R, I choose   U.   M.   Ⓓ

3) For **Game 3**, if A1 and/or A2 choose R, I choose   U.   Ⓜ   D.

4) For **Game 4**, if A1 and/or A2 choose R, I choose   Ⓤ   M.   D.

5) For **Game 5**, if A1 and/or A2 choose R, I choose   U.   M.   Ⓓ

B-type player

Example Round Earnings Sheet

Game Results						
Game	A1's Choice	A2's Choice	Your Choice	Payoff from A1	Payoff from A2	Total Payoff
1	(R) L	R (L)	(U) M D	50	50	100
2	(R) L	(R) L	U M (D)	10	40	50
3	(R) L	(R) L	U (M) D	40	30	70
4	R (L)	(R) L	(U) M D	45	0	45
5	R (L)	R (L)	U M (D)	45	50	95
				Your earnings for the five games:		360

Earnings from Correctly Anticipating Players' Responses		
(i) Number of times you thought the A1s would choose R: 0 1 2 (3) 4 5	Number of times the A1s actually chose R: 0 1 2 (3) 4 5	($0.25) $0.00
(ii) Number of times you thought the A2s would choose R: 0 1 2 3 4 (5)	Number of times the A2s actually chose R: 0 1 2 (3) 4 5	$0.25 ($0.00)
(iii) Number of times you thought the Bs would choose U: 0 (1) 2 3 4 5	Number of times the Bs actually chose U: 0 (1) 2 3 4 5	($0.25) $0.00
(iv) Number of times you thought the Bs would choose M: 0 1 2 3 (4) 5	Number of times the Bs actually chose M: 0 1 (2) 3 4 5	$0.25 ($0.00)
	Total Earnings:	$0.50

Total Earnings for the Round: _____360____ X $0.01 + ___$0.50___ = ___$4.10___

Instructions and Example Round Strategy and Earnings Sheets for Session 4

This is an experiment in group decision making that should take about 2 hours to complete. At the end of the experiment, you will be paid for your participation in cash. Different subjects may earn different amounts. What you earn depends partly on your decisions, partly on the decisions of others, and partly on chance. You will find it helpful to refer to **Figures 1 and 2**, your **Practice Round Strategy Sheet**, your **Example Round Strategy Sheet** and your **Example Round Earnings Sheet** as you read these instructions. After you read these instructions, please complete the quiz. When all participants have completed the quiz, the answers will be read out loud and any questions will be answered. **Please do not talk to or try to communicate with any other participants during this experiment. If you have a question during the experiment, please raise your hand and an experimenter will help you. If you fail to follow these instructions, you will be asked to leave and forfeit any moneys earned.**

1. **AN OVERVIEW:** During the experiment, you participate in two to five rounds. In each round, you play four games against randomly selected players. In each game, you receive tokens based on the decisions that you and the randomly selected player make. The first round is a practice round to help you learn the game. After the first round, you will participate in a single elimination tournament. You advance in the tournament by earning more tokens than a randomly selected participant. If you are eliminated in the first round, you are paid $0.01 for each token you earn in the first round of the tournament. If you are eliminated in the second round, you are paid

$0.05 for each token you earn in the second round of the tournament. If you are eliminated in the third round, you are paid $0.10 for each token you earn in the third round of the tournament. If you advance to the fourth round, you are paid $0.25 for each token you earn in the fourth round of the tournament. All players also receive a $5.00 participation fee.

2.   **THE PLAYERS:** There are twenty-four **players** randomly assigned to one of three types. Your type is shown at the top your **Practice Round Strategy Sheet**.

a)   There are eight A1-type players, which are referred to as A1s.

b)   There are eight A2-type players, which are referred to as A2s.

c)   There are eight B-type players, which are referred to as Bs.

3.   **THE GAME (Figures 1 and 2** provide a visual summary of the game):

a)   Player Matches for each game:

i)   A1 plays a B.

ii)   A2 plays a B.

iii)   B plays an A1 and an A2 at the same time.

b)   Payoffs (in tokens):

i)   A1's payoffs are the first numbers in parentheses in **Figure 1**.

ii)   A2's payoffs are the first numbers in parentheses in **Figure 2**.

iii)   B's payoffs are the second numbers in parentheses in **Figures 1 and 2**.

c)   Game Play: A1 and A2 may choose R or L. If A1 and/or A2 choose R, B may choose U, M or D.

i)   When A1 chooses L, A1 earns 60 and B earns 45.

ii)   When A2 chooses L, A2 earns 105 and B earns 50.

iii) When A1 chooses R, and

    a)   B chooses U, A1 earns 100 and B earns 50.

    b)   B chooses M, A1 earns 50 and B earns 40.

    c)   B chooses D, A1 earns 0 and B earns 10.

iv)   When A2 chooses R, and

    a)   B chooses U, A2 earns 100 and B earns 0.

    b)   B chooses M, A2 earns 50 and B earns 30.

    c)   B chooses D, A2 earns 0 and B earns 40.

4.   THE EXPERIMENT PROCEEDS AS FOLLOWS:

a)   In the experiment, you participate in two to five rounds. The first round, is a

practice round. After the practice round, you participate in a four round single

elimination tournament.

b)   Round Play:

i)   A round consists of four games.

ii)   Before each round you will complete a two part **Strategy Sheet.**

    a)   **Part I** asks you to anticipate how the randomly selected players

will play the four games. For example, on your **Example**

Strategy Sheet,

3 is circled in (i),

4 is circled in (ii),

1 is circled in (iii) and

3 is circled in (iv).

This implies that you think 3 of the randomly selected A1s will

choose R, and 1 will choose L.

You think 4 of the randomly selected A2s will choose R and

none will choose L.

You think 1 of the randomly selected Bs will choose U, 3 will

choose M and none will choose D.

Note that since there are only four games in a round the

sum of your responses to (iii) and (iv) must not exceed 4.

Also note that your responses to (i) through (iv) will be used

as a tie breaker. Therefore, the more accurate your

responses to (i) through (iv), the more likely you are to

advance in the tournament in the event of a tie.

b)   **Part II asks you to indicate how you will play each of the four**

games.

(1)   If you are an A1 or A2, you must choose between R or

L for each of the four games. You can pick either R or

L for all four games, or any combination of R and L.

For example, on your **Example Strategy Sheet,**

R is circled for **Game 1,**

R is circled for **Game 2,**

R is circled for **Game 3** and

L is circled for **Game 4.**

This implies that you choose to play R for games 1, 2

and 3, and L for game 4.

(2)   If you are a B, you must choose how you will play each

game provided A1 and /or A2 choose R. You can pick

either U, M or D for all four games, or any combination

of U, M and D. For example, on your **Example**

Strategy Sheet,

U is circled for **Game 1,**

D is circled for **Game 2,**

M is circled for **Game 3** and

U is circled for **Game 4.**

This implies that if A1 and/or A2 choose R you choose

to play U for games 1 and 4, M for game 3, and D for

game 2.

iii)   Once everyone has completed their **Strategy Sheets,** the sheets are

collected, and the match-ups are determined.

a)   For each game a B is randomly selected and his or her choice is

recorded on the A1s' and A2s' **Round Earnings Sheet.** For

example, if you are an A1 or A2 and

the first (randomly selected) B chose U,

the second (randomly selected) B chose M,

the third (randomly selected) B chose D and

the fourth (randomly selected) B chose D,

then, on your **Example Round Earnings Sheet,**

U is circled for Game 1,

M is circled for Game 2,

D is circled for Game 3 and

D is circled for Game 4.

b)   For each game an A1 is randomly selected and his or her choice

is recorded on the Bs' **Round Earnings Sheet.** For example, if

you are a B and

the first (randomly selected) A1 chose R,

the second (randomly selected) A1 chose R,

the third (randomly selected) A1 chose R and

the fourth (randomly selected) A1 chose L,

then, on your **Example Round Earnings Sheet,**

R is circled for Game 1,

R is circled for Game 2,

R is circled for Game 3 and

L is circled for Game 4.

c)   For each game an A2 is randomly selected and his or her choice

is recorded on the Bs' **Round Earnings Sheet**. For example, if

you are a B and

the first (randomly selected) A2 chose L,

the second (randomly selected) A2 chose R,

the third (randomly selected) A2 chose R and

the fourth (randomly selected) A2 chose R,

then, on your **Example Round Earnings Sheet**,

L is circled for Game 1,

R is circled for Game 2,

R is circled for Game 3 and

R is circled for Game 4.

iv)   After the match-ups are determined, the results are recorded and

returned to you on your **Round Earnings Sheet**. Your earnings for

the round (in tokens) is equal to the sum of your earnings for **Games 1**

through **4**. For example, on your **Example Earnings Record Sheet**, if

you are an A1, A2 or B, then your earnings in tokens for the round

would be **210, 255** or **265**. The number of times you correctly

anticipated the randomly selected players' choices is also recorded. For

instance, on your **Example Round Earnings Sheet**, since 3 was

circled for (i) on your **Example Round Strategy Sheet** and 3 of the

randomly selected A1s chose R, you would have responded correctly.

Since 4 was circled for (ii) on your **Example Round Strategy Sheet**
and 3 of the randomly selected A2s chose R, you would have
responded incorrectly. Since 1 was circled for (iii) on your **Example
Round Strategy Sheet** and 1 of the randomly selected Bs chose U,
you would have responded correctly. Since 3 was circled for (iv) on
your **Example Round Strategy Sheet** and 1 of the randomly selected
Bs chose M, you would have responded incorrectly. Therefore, on
your **Example Round Earnings Sheet**, you would have correctly
anticipated the randomly selected players choices twice.

c)   Tournament Play:

    i)   **Practice Round:** Once all 24 participants have completed their
Practice Round Strategy Sheets, the sheets are collected. The results
of the **Practice Round** are recorded and returned to you on your
Practice Round Earnings Sheet along with your **Round 1 Strategy
Sheet**. Please carefully review your **Practice Round Earnings Sheet**
and complete your **Round 1 Strategy Sheet**.

    ii)   **Round 1:** After all 24 participants have completed their **Round 1
Strategy Sheets**, the sheets are collected. The results of **Round 1** are
recorded and returned to you on your **Round 1 Earnings Sheet**. If
you earn more tokens than the participant of your type that you are
matched with, then you advance to **Round 2**. For example, on your

Example Round Earnings Sheet, the participant you are matched with earned 200 tokens for the round. Therefore, you would advance to **Round 2**, while the participant you are matched with would be eliminated. In the event of a tie, the participant that made the most correct responses to (i) through (iv) for **Round 1** advances. For instance, if your earnings in tokens on your **Example Round Earnings Sheet** was 200, then you and the participant you are matched with would have tied. If the participant you are matched with had correctly responded to (i) through (iv) three times, he/she would advance to **Round 2** and you would be eliminated since you have correctly responded twice to (i) through (iv) in the example round. If you and the participant you are matched with earn the same number of tokens and respond correctly to (i) through (iv) the same number of times, then the tie is broken with a coin toss. If you are eliminated, you are paid immediately and allowed to leave. If you advance, you receive a **Round 2 Strategy Sheet**. Please carefully review your **Round 1 Earnings Sheet** and complete your **Round 2 Strategy Sheet**.

iii) **Round 2:** After the remaining 12 participants have completed their **Round 2 Strategy Sheets**, the sheets are collected. The results of **Round 2** are recorded and returned to you on your **Round 2 Earnings Sheet**. If you earn more tokens than the new participant of your type that you are matched with, then you advance to **Round 3**. In the event

of a tie, the participant that made the most correct responses to (i)

through (iv) for **Round 2** advances. If you are still tied, then the tie is

broken with a coin toss. If you are eliminated, you are paid immediately

and allowed to leave. If you advance, you receive a **Round 3 Strategy**

Sheet. Please carefully review your **Round 2 Earnings Sheet** and

complete your **Round 3 Strategy Sheet**.

iv) **Round 3:** After the remaining 6 participants have completed their

Round 3 Strategy Sheets, the sheets are collected. The results of

Round 3 are recorded and returned to you on your **Round 3 Earnings**

Sheet. If you earn more tokens than the only remaining participant of

your type, then you advance to **Round 4**. In the event of a tie, the

participant that made the most correct responses to (i) through (iv) for

Round 3 advances. If you are still tied, then the tie is broken with a

coin toss. If you are eliminated, you are paid immediately and allowed

to leave. If you advance, you receive a **Round 4 Strategy Sheet**.

Please carefully review your **Round 3 Earnings Sheet** and complete

your **Round 4 Strategy Sheet**.

v) **Round 4:** After the remaining 3 participants (one of each type) have

completed their **Round 4 Strategy Sheets**, the sheets are collected.

The results of **Round 4** are recorded and returned to you on your

Round 4 Earnings Sheet. Please wait for an experimenter to call on you so that you can be paid.

5. **EARNINGS FOR THE EXPERIMENT:** In addition to a $5.00 participation fee, your earnings for the experiment include the value of your tokens earned for the last round in which you participated.

Last Round of Participation	Value of a Token
Round 1	$0.01
Round 2	$0.05
Round 3	$0.10
Round 4	$0.25

For instance, if you are eliminated in **Round 1** and you earned 360 tokens in **Round 1**, then you earn $5.00 + (360 X $0.01) = $8.60. If you are eliminated in **Round 2** and you earned 360 tokens in **Round 2**, then you earn $5.00 + (360 X $0.05) = $23.00. If you are eliminated in **Round 3** and you earned 360 tokens in **Round 3**, then you earn $5.00 + (360 X $0.10) = $41.00. If you advance to **Round 4** and you earned 360 tokens in **Round 4**, then you earn $5.00 + (360 X $0.25) = $95.00.

QUIZ

1. If A1 chooses L, and A2 chooses L,

   a) what is A1's payoff?

   b) what is A2's payoff?

   c) what is B's payoff from playing A1?

   d) what is B's payoff from playing A2?

   e) what is B's total payoff?

2. If A1 chooses R, A2 chooses L, and B chooses D,

   a) what is A1's payoff?

   b) what is A2's payoff?

   c) what is B's payoff from playing A1?

   d) what is B's payoff from playing A2?

   e) what is B's total payoff?

3. What type of participant are you matched with to determine if you advance in the tournament?

4. What type(s) of players do you play in each of the four games in a round?

5. If you earn 395 tokens in a round and you are match with a participant that earned 380 tokens, do you advance to the next round?

6. If you and the participant you are matched with earn the same number of tokens in a round and you responded correctly to (i) and (iii) and the participant you are matched with responded correctly to (i), (ii) and (iv), do you advance to the next round?

7. If you are eliminated in **Round 3** and you earned 350 tokens in **Round 3**, how much do you earn for the experiment?

A1-type player

Example Round Strategy Sheet

Part I: Please indicate how you anticipate other players will play the four games by completing the statements below. Complete statements (i) through (iv) by circling the appropriate number. **Please circle only one number for each statement. Remember that the number of correct responses you make will be used to determine who advances in the tournament in the event of a tie.**

(i)   I think the (randomly selected) A1s will choose R in [0   1   2   ③   4] of the four games.

(ii)   I think the (randomly selected) A2s will choose R in [0   1   2   3   ④] of the four games.

(iii) I think the (randomly selected) Bs will choose U in [0   ①   2   3   4] of the four games.

(iv)   I think the (randomly selected) Bs will choose M in [0   1   2   ③   4] of the four games. **Note that the sum of your responses in (iii) and (iv) should not exceed 4.**

Part II: Please indicate how you will play each of the four games in this round by circling the appropriate letter below. **Please circle only one letter for each game.**

1) For **Game 1**, I choose   ⓡ   L.

2) For **Game 2**, I choose   ⓡ   L.

3) For **Game 3**, I choose   ⓡ   L.

4) For **Game 4**, I choose   R.   Ⓛ

A1-type player

Example Round Earnings Sheet

Game Results			
Game	B's Choices	Your Choices	Your Payoff
1	(U) M D	(R) L	100
2	U (M) D	(R) L	50
3	U M (D)	(R) L	0
4	U M (D)	R (L)	60
	Your payoff in tokens for the round:		210

Your Responses to Part I	Randomly Selected Players' Choices	Correct
(i) Number of times you thought the A1s would choose R: 0 1 2 (3) 4	Number of times the A1s actually chose R: 0 1 2 (3) 4	(Yes) No
(ii) Number of times you thought the A2s would choose R: 0 1 2 3 (4)	Number of times the A2s actually chose R: 0 1 2 (3) 4	Yes (No)
(iii) Number of times you thought the Bs would choose U: 0 (1) 2 3 4	Number of times the Bs actually chose U: 0 (1) 2 3 4	(Yes) No
(iv) Number of times you thought the Bs would choose M: 0 1 2 (3) 4	Number of times the Bs actually chose M: 0 (1) 2 3 4	Yes (No)
Number of times you correctly anticipated the randomly selected players' choices:		2

Tournament Advancement:

The round earnings in tokens of the participant you are matched with: _____200_____

In the Event of a Tie: The number of times the participant you are

matched with responded correctly to (i) through (iv): _____3_____

Would you have advanced in the tournament? (Yes) No

A2-type player

Example Round Strategy Sheet

Part I: Please indicate how you anticipate other players will play the four games by completing the statements below. Complete statements (i) through (iv) by circling the appropriate number. **Please circle only one number for each statement. Remember that the number of correct responses you make will be used to determine who advances in the tournament in the event of a tie.**

(i) I think the (randomly selected) A1s will choose R in [0   1   2 ③ 4] of the four games.

(ii) I think the (randomly selected) A2s will choose R in [0   1   2   3 ④] of the four games.

(iii) I think the (randomly selected) Bs will choose U in [0 ① 2   3   4] of the four games.

(iv) I think the (randomly selected) Bs will choose M in [0   1   2 ③ 4] of the four games. **Note that the sum of your responses in (iii) and (iv) should not exceed 4.**

Part II: Please indicate how you will play each of the four games in this round by circling the appropriate letter below. **Please circle only one letter for each game.**

1) For **Game 1**, I choose   Ⓡ   L.

2) For **Game 2**, I choose   Ⓡ   L.

3) For **Game 3**, I choose   Ⓡ   L.

4) For **Game 4**, I choose   R.   Ⓛ

A2-type player

Example Round Earnings Sheet

Game Results			
Game	B's Choices	Your Choices	Your Payoff
1	Ⓤ M D	Ⓡ L	100
2	U Ⓜ D	Ⓡ L	50
3	U M Ⓓ	Ⓡ L	0
4	U M Ⓓ	R Ⓛ	105
	Your payoff in tokens for the round:		255

Your Responses to Part I	Randomly Selected Players' Choices	Correct
(i) Number of times you thought the A1s would choose R: 0 1 2 ③ 4	Number of times the A1s actually chose R: 0 1 2 ③ 4	Ⓨes No
(ii) Number of times you thought the A2s would choose R: 0 1 2 3 ④	Number of times the A2s actually chose R: 0 1 2 ③ 4	Yes Ⓝo
(iii) Number of times you thought the Bs would choose U: 0 ① 2 3 4	Number of times the Bs actually chose U: 0 ① 2 3 4	Ⓨes No
(iv) Number of times you thought the Bs would choose M: 0 1 2 ③ 4	Number of times the Bs actually chose M: 0 ① 2 3 4	Yes Ⓝo
Number of times you correctly anticipated the randomly selected players' choices:		2

Tournament Advancement:

The round earnings in tokens of the participant you are matched with: 200

In the Event of a Tie: The number of times the participant you are

matched with responded correctly to (i) through (iv):   3

Would you have advanced in the tournament?   Ⓨes   No

B-type player

Example Round Strategy Sheet

Part I: Please indicate how you anticipate other players will play the four games by completing the statements below. Complete statements (i) through (iv) by circling the appropriate number. **Please circle only one number for each statement. Remember that the number of correct responses you make will be used to determine who advances in the tournament in the event of a tie.**

(i) I think the (randomly selected) A1s will choose R in [0 1 2 ③ 4] of the four games.

(ii) I think the (randomly selected) A2s will choose R in [0 1 2 3 ④] of the four games.

(iii) I think the (randomly selected) Bs will choose U in [0 ① 2 3 4] of the four games.

(iv) I think the (randomly selected) Bs will choose M in [0 1 2 ③ 4] of the four games. **Note that the sum of your responses in (iii) and (iv) should not exceed 4.**

Part II: Please indicate how you will play each of the four games in this round by circling the appropriate letter below. **Please circle only one letter for each game.**

1) For **Game 1**, if A1 and/or A2 choose R, I choose   Ⓤ   M.   D.

2) For **Game 2**, if A1 and/or A2 choose R, I choose   U.   M.   Ⓓ

3) For **Game 3**, if A1 and/or A2 choose R, I choose   U.   Ⓜ   D.

4) For **Game 4**, if A1 and/or A2 choose R, I choose   Ⓤ   M.   D.

B-type player

Example Round Earnings Sheet

Game Results						
Game	A1's Choice	A2's Choice	Your Choice	Payoff from A1	Payoff from A2	Total Payoff
1	(R) L	R (L)	(U) M D	50	50	100
2	(R) L	(R) L	U M (D)	10	40	50
3	(R) L	(R) L	U (M) D	40	30	70
4	R (L)	(R) L	(U) M D	45	0	45

Your payoff in tokens for the round: **265**

Your Responses to Part I	Randomly Selected Players' Choices	Correct
(i) Number of times you thought the A1s would choose R: 0 1 2 (3) 4	Number of times the A1s actually chose R: 0 1 2 (3) 4	(Yes) No
(ii) Number of times you thought the A2s would choose R: 0 1 2 3 (4)	Number of times the A2s actually chose R: 0 1 2 (3) 4	Yes (No)
(iii) Number of times you thought the Bs would choose U: 0 (1) 2 3 4	Number of times the Bs actually chose U: 0 (1) 2 3 4	(Yes) No
(iv) Number of times you thought the Bs would choose M: 0 1 2 (3) 4	Number of times the Bs actually chose M: 0 (1) 2 3 4	Yes (No)
Number of times you correctly anticipated the randomly selected players' choices:		2

Tournament Advancement:

The round earnings in tokens of the participant you are matched with: **200**

In the Event of a Tie: The number of times the participant you are

matched with responded correctly to (i) through (iv):   **3**

Would you have advanced in the tournament?   (Yes) No

Figures 1 and 2

Each subject had a copy of the Figure C1 below.

Figure 1: Payoff tree for the A1 and B players.
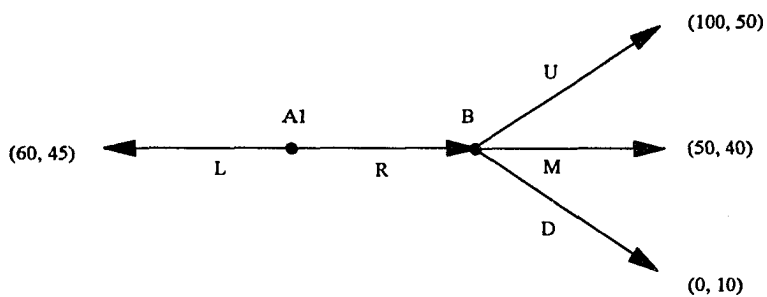
Figure 2: Payoff tree for the A2 and B players.
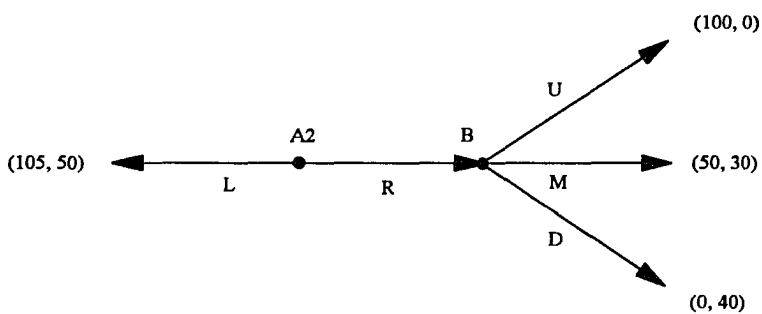
Figure C1: Extensive form game given to subjects to determine their payoffs

APPENDIX D. EXPERIMENTAL DATA

General Data Definitions

Session: Sessions 2 and 3 paid subjects based on their performance in rounds 2 through 5, while session 4 used the tournament incentive mechanism described above. Note: session 0 and 1 were pilot sessions that are not reported here.

Round::   Each session had five rounds. Round 1 was a practice round in which the incentive mechanisms were not binding. In session 4, Round 2 was the first round of the single elimination tournament.

Specific Definitions for Strategy Sheet Response Data

Pnumber: Represents the subject's number. For sessions 2 and 3, each subject of a given type was identified with a number 1 through 5. For session 4, each subject of a given type was identified with a number 1 through 8.

PPart1i: The number of randomly selected A1s that the subject predicted to choose R.

PPart1ii: The number of randomly selected A2s that the subject predicted to choose R.

PPart1iii: The number of randomly selected Bs that the subject predicted to choose U.

PPart1iv: The number of randomly selected Bs that the subject predicted to choose M.

G[Game number]:   The subject's strategy choice for game [Game number]. For type A1 or A2, 1 denotes R and 2 denotes L. For type B, 1 denotes U, 2 denotes M and 3 denotes D.

Strategy Sheet Response Data

Strategy sheet response data for type A1 players

Session	Pnumber	Round	PPart1i	PPart1ii	PPart1iii
2	1	1	1	2	1
2	1	2	2	3	2
2	1	3	1	2	2
2	1	4	2	3	3
2	1	5	1	2	2
2	2	1	4	4	1
2	2	2	4	2	2
2	2	3	3	2	3
2	2	4	3	1	3
2	2	5	3	1	2
2	3	1	3	1	0
2	3	2	3	1	1
2	3	3	3	5	1
2	3	4	3	0	3
2	3	5	3	1	3
2	4	1	1	0	1
2	4	2	1	0	2
2	4	3	0	0	2
2	4	4	2	1	3
2	4	5	1	1	2
2	5	1	3	1	1
2	5	2	2	1	1
2	5	3	1	0	0
2	5	4	3	1	1
2	5	5	2	1	1

3	1	1	3	5	4
3	1	2	3	5	1
3	1	3	3	5	1
3	1	4	5	2	0
3	1	5	4	1	2
3	2	1	2	0	1
3	2	2	4	1	2
3	2	3	2	2	2
3	2	4	2	1	2
3	2	5	4	0	1
3	3	1	3	4	2
3	3	2	4	2	2
3	3	3	2	1	2
3	3	4	3	0	2
3	3	5	4	0	2
3	4	1	2	3	4
3	4	2	4	1	2
3	4	3	3	1	2
3	4	4	3	0	2
3	4	5	4	0	2
3	5	1	3	4	4
3	5	2	3	2	3
3	5	3	3	1	2
3	5	4	3	1	2
3	5	5	3	1	1
4	1	1	2	3	1
4	1	2	2	2	2
4	2	1	3	4	3

4	2	2	2	0	2
4	2	3	2	0	2
4	3	1	2	3	1
4	3	2	2	1	2
4	3	3	1	0	2
4	3	4	1	0	1
4	3	5	1	0	2
4	4	1	2	0	2
4	4	2	2	0	2
4	5	1	3	2	1
4	5	2	2	1	2
4	5	3	1	0	1
4	6	1	3	2	0
4	6	2	1	1	1
4	7	1	2	3	2
4	7	2	1	3	3
4	8	1	2	4	2
4	8	2	1	0	2
4	8	3	1	0	2
4	8	4	1	0	2

Strategy sheet response data for type A1 players continued

PPartliv	G1	G2	G3	G4	G5
2	2	2	1	2	2
1	2	2	2	1	1
3	2	2	1	1	2
1	1	2	1	2	2
2	2	1	1	2	2

4	1	1	2	1	1
4	1	1	2	1	1
2	1	1	2	2	1
2	1	2	2	1	1
3	1	1	1	1	1
3	2	1	1	2	1
3	2	1	1	2	1
3	2	2	1	1	1
2	2	1	1	2	1
2	2	1	1	1	1
4	2	2	2	2	2
3	2	2	2	2	2
3	2	2	2	2	2
2	2	2	1	2	2
3	2	2	1	2	2
3	1	2	1	2	1
3	1	1	2	2	2
3	2	2	1	2	1
3	1	2	2	1	1
3	2	1	2	1	2
3	1	1	2	2	1
4	1	1	2	2	1
3	1	1	1	1	1
3	1	1	1	1	1
3	2	1	1	2	1
4	2	1	2	1	2
2	2	2	2	1	1
2	2	2	2	2	2

1	1	2	1	2	1
3	2	2	1	2	2
2	1	2	1	2	1
2	1	2	2	2	1
2	1	2	1	2	1
3	1	1	1	1	1
3	1	2	1	2	1
1	1	2	1	2	1
3	1	1	2	2	1
3	2	1	2	1	2
3	1	1	2	1	1
3	1	1	2	2	2
3	2	2	1	1	2
2	2	2	1	2	1
3	2	2	2	1	2
3	2	2	2	1	2
3	2	2	1	2	2
2	1	2	2	1	0
1	1	2	1	2	0
1	2	1	2	1	0
1	1	2	1	2	0
1	1	2	2	1	0
3	1	1	2	2	0
1	2	1	2	1	0
2	2	1	1	1	0
3	2	1	1	2	0
2	1	1	1	2	0
2	1	2	2	2	0

2	1	2	2	1	0
3	2	1	2	1	0
1	2	1	1	2	0
2	2	1	1	1	0
2	1	2	1	1	0
2	2	1	1	1	0
2	1	2	2	1	0
1	2	2	2	1	0
2	1	1	2	2	0
1	2	2	2	1	0
2	2	1	2	2	0
2	2	1	2	2	0

Strategy sheet response data for type A2 players

Session	Pnumber	Round	PPart1i	PPart1ii	PPart1iii
2	1	1	3	0	1
2	1	2	3	0	2
2	1	3	2	0	4
2	1	4	3	1	3
2	1	5	2	1	4
2	2	1	3	0	2
2	2	2	2	0	2
2	2	3	2	1	2
2	2	4	3	1	2
2	2	5	2	1	2
2	3	1	2	2	1
2	3	2	3	1	2
2	3	3	4	1	3

2	3	4	4	0	3
2	3	5	3	1	3
2	4	1	3	2	1
2	4	2	3	4	1
2	4	3	2	0	3
2	4	4	3	0	3
2	4	5	3	1	3
2	5	1	2	5	3
2	5	2	3	2	2
2	5	3	1	2	2
2	5	4	2	1	3
2	5	5	1	2	2
3	1	1	4	5	1
3	1	2	2	0	3
3	1	3	1	1	3
3	1	4	2	0	2
3	1	5	4	0	2
3	2	1	4	3	1
3	2	2	3	3	2
3	2	3	2	1	3
3	2	4	0	0	4
3	2	5	5	0	2
3	3	1	5	5	5
3	3	2	4	3	3
3	3	3	2	1	2
3	3	4	4	0	2
3	3	5	4	0	1
3	4	1	4	3	2

3	4	2	5	1	3
3	4	3	2	0	2
3	4	4	3	1	2
3	4	5	4	0	2
3	5	1	3	0	5
3	5	2	1	0	2
3	5	3	5	0	5
3	5	4	5	0	5
3	5	5	5	0	5
4	1	1	3	1	1
4	1	2	1	0	2
4	1	3	1	0	1
4	1	4	1	0	1
4	2	1	1	1	1
4	2	2	2	1	0
4	3	1	3	2	2
4	3	2	2	1	2
4	4	1	3	1	2
4	4	2	2	0	2
4	4	3	1	0	0
4	5	1	2	0	0
4	5	2	1	0	1
4	5	3	1	0	1
4	5	4	1	0	1
4	5	5	2	0	1
4	6	1	2	0	3
4	6	2	1	0	3
4	7	1	2	2	2

4	7	2	2	2	2
4	8	1	3	1	2
4	8	2	1	1	1
4	8	3	1	0	1

Strategy sheet response data for type A2 players continued

PPart1iv	G1	G2	G3	G4	G5
4	2	2	2	2	2
3	2	2	2	2	2
0	2	2	2	2	2
2	2	2	2	2	2
1	2	2	2	2	2
3	2	2	2	2	2
3	2	2	2	2	2
3	2	2	2	2	2
3	2	2	2	2	2
3	2	2	2	2	2
4	2	1	1	2	2
3	1	2	2	2	1
2	2	2	2	2	2
2	2	2	2	2	2
2	2	2	2	2	2
4	2	2	1	2	2
3	2	2	1	2	2
2	2	2	2	2	2
2	2	2	2	2	2
2	2	2	2	2	2
2	1	1	1	2	1

2	1	2	1	2	1
2	2	1	2	1	2
2	1	1	2	2	1
2	2	1	2	1	2
4	2	2	2	2	2
2	2	2	2	2	2
2	2	2	2	2	2
3	2	2	2	2	2
3	2	2	2	2	2
3	1	2	1	1	1
3	1	2	1	2	1
2	1	2	2	2	1
1	2	2	2	2	2
3	2	2	2	2	2
0	2	2	2	2	2
2	2	2	2	2	2
3	2	2	2	2	2
3	2	2	2	2	2
3	2	2	2	2	2
3	2	1	2	2	1
3	1	2	2	2	2
3	2	2	2	2	2
3	2	2	2	2	2
3	2	2	2	2	2
0	2	2	2	2	2
3	2	2	2	2	2
0	2	2	2	2	2
0	2	2	2	2	2

0	2	2	2	2	2
3	2	2	2	2	0
1	2	2	2	2	0
3	2	2	2	2	0
3	2	2	2	2	0
2	1	1	1	1	0
2	2	2	2	2	0
2	1	2	1	2	0
1	2	1	2	2	0
2	2	2	2	2	0
2	2	2	2	2	0
4	2	2	2	2	0
4	2	2	2	2	0
3	2	2	2	2	0
3	2	2	2	2	0
3	2	2	2	2	0
3	2	2	2	2	0
1	2	2	2	2	0
1	2	2	2	2	0
2	2	1	2	2	0
2	2	2	2	2	0
2	2	1	2	2	0
2	2	2	2	2	0
2	2	2	2	2	0

Strategy sheet response data for type B players

Session	Pnumber	Round	PPart1i	PPart1ii	PPart1iii
2	1	1	1	0	5
2	1	2	0	1	2
2	1	3	1	1	2
2	1	4	1	1	2
2	1	5	1	1	2
2	2	1	4	0	3
2	2	2	3	1	3
2	2	3	2	1	2
2	2	4	3	1	2
2	2	5	3	1	2
2	3	1	4	0	4
2	3	2	4	0	3
2	3	3	4	5	3
2	3	4	3	1	3
2	3	5	2	1	2
2	4	1	1	0	1
2	4	2	2	0	1
2	4	3	2	0	2
2	4	4	4	0	3
2	4	5	5	0	5
2	5	1	3	4	4
2	5	2	3	4	5
2	5	3	5	4	4
2	5	4	2	3	4
2	5	5	3	3	3
3	1	1	3	4	3

3	1	2	4	3	2
3	1	3	2	2	2
3	1	4	3	2	2
3	1	5	3	1	2
3	2	1	2	3	2
3	2	2	4	3	4
3	2	3	3	3	1
3	2	4	1	1	2
3	2	5	4	0	1
3	3	1	5	0	0
3	3	2	5	0	0
3	3	3	5	1	2
3	3	4	5	0	2
3	3	5	4	0	1
3	4	1	2	4	1
3	4	2	5	1	2
3	4	3	1	1	2
3	4	4	2	0	2
3	4	5	3	0	1
3	5	1	3	4	3
3	5	2	4	2	1
3	5	3	4	1	2
3	5	4	4	1	2
3	5	5	4	0	2
4	1	1	3	0	1
4	1	2	2	1	1
4	2	1	3	2	1
4	2	2	2	2	2

4	2	3	2	2	1
4	3	1	3	2	2
4	3	2	2	3	1
4	4	1	4	0	4
4	4	2	4	0	4
4	4	3	4	0	4
4	4	4	4	0	4
4	4	5	4	0	4
4	5	1	2	3	2
4	5	2	3	2	0
4	6	1	2	2	2
4	6	2	2	3	3
4	6	3	3	2	2
4	6	4	2	0	1
4	7	1	3	0	2
4	7	2	2	0	2
4	8	1	2	0	1
4	8	2	2	0	2
4	8	3	2	0	2

Strategy sheet response data for type B players continued

PPartIiv	G1	G2	G3	G4	G5
0	1	1	1	1	1
3	1	2	1	1	1
3	1	1	1	1	1
3	1	1	1	1	1
3	1	1	1	1	1
2	2	1	2	3	2

2	2	1	2	3	2
2	2	1	2	3	2
2	2	1	2	3	2
2	2	1	2	3	2
1	1	1	1	1	1
2	1	1	1	1	1
2	1	1	1	1	1
2	1	1	1	1	1
3	1	1	1	1	1
3	2	2	2	2	2
4	2	2	2	2	2
2	2	2	2	2	2
2	2	2	2	2	2
0	1	1	1	1	1
4	3	2	2	2	2
3	1	3	2	1	3
4	2	1	3	2	1
3	2	2	2	2	2
3	2	2	2	2	2
2	1	1	2	3	2
1	2	1	1	2	1
3	2	1	3	1	1
3	3	3	3	3	3
3	1	1	3	1	1
4	2	1	3	3	1
3	1	2	1	2	1
4	2	3	3	2	2
4	2	2	2	2	2

4	2	2	2	2	3
5	2	2	2	2	2
5	2	2	2	2	2
3	2	2	2	2	2
3	2	2	2	2	2
3	2	2	2	2	2
4	2	2	2	2	2
4	2	2	2	2	2
4	2	2	2	2	2
4	2	2	2	2	2
4	2	2	2	2	2
2	1	2	2	1	1
3	2	2	1	2	2
3	1	1	1	1	1
3	1	1	1	1	1
3	1	1	1	1	1
3	3	2	3	3	0
3	3	2	3	3	0
1	1	3	2	1	0
2	1	1	3	1	0
2	2	2	2	2	0
1	1	2	2	2	0
2	2	2	2	2	0
0	3	3	3	3	0
0	1	1	1	1	0
0	1	1	1	1	0
0	1	1	1	1	0
0	1	1	1	1	0

1	2	3	1	2	0
4	2	1	3	2	0
1	1	2	1	3	0
1	3	2	1	2	0
2	2	3	1	2	0
3	1	3	1	3	0
2	2	1	2	1	0
1	1	2	2	3	0
3	2	2	2	2	0
1	2	2	2	2	0
2	2	2	2	2	0

Specific Definitions for History Data

APart1i: The number of randomly selected A1s that actually chose R.

APart1ii: The number of randomly selected A2s that actually chose R.

APart1iii: The number of randomly selected Bs that actually chose U.

APart1iv: The number of randomly selected Bs that actually chose M.

[Player type]G[Game number]P: The subject of type [Player type] whose strategy was randomly selected for game [Game number]. For sessions 2 and 3, each subject of a given type was identified with a number 1 through 5. For session 4, each subject of a given type was identified with a number 1 through 8.

[Player type]G[Game number]R: The choice of the randomly selected subject of type

[Player type] for game [Game number]. For type A1 or

A2, 1 denotes R and 2 denotes L. For type B, 1 denotes

U, 2 denotes M and 3 denotes D.

History Data

Session	Round	APart1i	APart1ii	APart1iii	APart1iii
2	1	3	1	2	3
2	2	1	1	2	2
2	3	3	1	3	2
2	4	1	1	2	3
2	5	3	0	3	2
3	1	4	1	2	2
3	2	1	1	2	3
3	3	4	0	2	3
3	4	4	0	1	3
3	5	2	0	1	3
4	1	1	0	2	1
4	2	1	0	1	3
4	3	1	0	1	3
4	4	2	0	2	0
4	5	3	0	4	0

A1G1P	A1G1R	A2G1P	A2G1R	BG1P	BG1R
4	2	4	2	2	2
3	2	2	2	2	2
5	2	1	2	4	2

3	2	2	2	1	1
4	2	3	2	4	1
1	1	4	2	4	2
5	2	2	1	4	2
3	1	4	2	4	2
4	1	2	2	1	3
1	2	4	2	4	2
5	2	6	2	4	3
6	2	4	2	8	2
3	2	4	2	6	2
8	2	1	2	4	1
3	1	5	2	4	1

A1G2P	A1G2R	A2G2P	A2G2R	BG2P	BG2R
2	1	5	1	3	1
4	2	1	2	4	2
4	2	5	1	2	1
4	2	5	1	4	2
1	1	1	2	5	2
5	2	5	2	1	1
3	2	4	2	1	1
4	1	3	2	3	2
1	1	5	2	4	2
4	1	3	2	2	2
7	2	3	2	1	2
1	2	5	2	2	1

2	2	1	2	4	1
8	1	5	2	6	3
3	1	5	2	4	1

A1G3P	A1G3R	A2G3P	A2G3R	BG3P	BG3R
5	1	2	2	1	1
1	2	5	1	1	1
1	1	2	2	3	1
2	2	4	2	3	1
3	1	2	2	2	2
4	1	1	2	3	2
2	2	1	2	2	1
2	2	2	2	5	1
5	2	4	2	2	2
2	1	1	2	1	3
3	2	8	2	5	1
8	2	2	2	3	2
5	1	5	2	2	2
3	1	5	2	4	1
3	1	5	2	4	1

A1G4P	A1G4R	A2G4P	A2G4R	BG4P	BG4R
1	2	1	2	4	2
2	1	3	2	3	1
3	1	3	2	5	2
5	1	1	2	5	2
2	1	4	2	1	1
2	1	2	1	2	3

1	2	3	2	3	2
5	1	5	2	2	2
3	1	3	2	3	2
3	2	2	2	3	2
2	1	7	2	7	1
4	1	1	2	6	2
8	2	8	2	8	2
3	2	1	2	6	3
3	2	5	2	4	1

A1G5P[a]	A1G5R	A2G5P	A2G5R	BG5P	BG5R
3	1	3	2	5	2
5	2	4	2	5	3
2	1	4	2	1	1
1	2	3	2	2	2
5	2	5	2	3	1
3	1	3	2	5	1
4	1	5	2	5	2
1	1	1	2	1	1
2	1	1	2	5	1
5	2	5	2	5	1

[a] There are only ten sets of observations for Game 5 because the tournament had only four rounds. These ten observations are for sessions 2 and 3.