Court-Appointed Experts and Accuracy in Adversarial Litigation*

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Abstract

Concerned about evidence distortion arising due to litigants' strong incentive to misrepresent information provided to fact-finders, legal scholars and commentators have long suggested that courts appoint their own advisors for neutral information regarding disputes. This paper examines the litigants' problem of losing incentive to provide information when judges seek the advice of court-appointed experts. Within a standard litigation game framework, we find that assigning court-appointed experts involves a trade-off: although such experts help judges obtain more information overall, thereby reducing the number of errors during trials, they weaken litigants' incentive to supply expert information, thus undermining the adversarial nature of the current American legal system.

Keywords: litigation game; court-appointed expert; persuasion game; evidence distortion.

JEL: C72; D82; K41.

1 Introduction

The current American legal system is adversarial and requires litigants to provide information to a judge for decision-making. This decentralized method for collecting information has been praised by many scholars including Posner (1988, 1999) who presented strong arguments for such decentralized institutions. In general, economic analysis has supported such decentralized systems of evidence collection. The main intuition obtained from various economic models, as demonstrated in an early contribution by Milgrom and Roberts (1986), is that information held by litigants is eventually revealed to the fact-finder because of the competition between

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them: a piece of evidence detrimental to one party is beneficial to the other, and therefore one of the competing parties eventually reveals any relevant evidence. This intuition has been confirmed to be robust in a more general environment and has strongly supported the American legal system's current form.[1]

Despite decentralization being strongly supported in evidence collection, both scholars and practitioners have long noted its shortcomings, particularly its contribution to evidence distortion, because competing litigants have strong incentives to misrepresent their evidence and thus influence the courts' final decisions. Thus, there have been numerous reform proposals suggesting that courts appoint their own experts, thereby enhancing the inquisitorial component in the American legal system.[2] A large body of literature has examined these issues and presented various proposals; see, for example, Cecil and Willging (1994), Deason (1998), Epstein (1992, 1993), Faigman (1996), Pinsky (1997), and Reisinger (1998) for arguments that promote the use of court-appointed experts. Erichson (1998) and Bernstein (2008) have suggested that judges use court-appointed experts as advisors on issues such as the admissibility of scientific evidence rather than using them as sources of information.

The general idea behind these proposals is simple yet compelling: by appointing a court advisor, judges have access to a piece of neutral evidence that can help them determine the nature of disputes more accurately, thereby increasing the accuracy of their final decisions. However, this reasoning could be flawed because it fails to consider the ways in which litigants may alter their behavior in response to the appointment of court advisors. In this paper, we demonstrate, within the standard litigation game framework, that the presence of court-appointed experts weakens litigants' incentive to collect and provide evidence to judges. More precisely, litigants expect that the expert information provided by them will have little influence on the judges' decisions if judges obtain outside information from court-appointed experts. Our primary results show that this expectation weakens litigants' incentive to provide expert information in equilibrium. We also show that, despite receiving less information from the litigants, judges obtain more information about the issues in disputes overall when court-appointed experts are present; therefore, they make less errors during decision-making

[1] Milgrom and Roberts (1986) employ a persuasion-game framework for their analysis. See, among others, Froeb and Kobayashi (1996), Shin (1998), Demougin and Fluet (2008), and Kim (2014a, 2017a) for the same line of research. Also see Froeb and Kobayashi (2001), Parisi (2002), Emons and Fluet (2009a,b), and Pavesi and Scotti (2014) for related research. While these papers assume that the litigants always supply biased information to the fact-finder, Kim (2016) studies a situation in which a litigant is willing to provide *unbiased* information. Kim (2017b) studies a situation in which the fact-finder does not observe the *quality* of information proffered by the litigants.

[2] For example, see Runkle (2001), who discusses the structure of the Court Appointed Scientific Experts Program created by the American Association for the Advancement of Science to help judges obtain independent experts. Also see Hillman (2002), Adrogue and Ratliff (2003), and Kaplan (2006), among others. Based on his experience as Judge Richard Posner's court-appointed economic expert, Sidak (2013) argues for court-appointed, neutral economic experts. Many reformers, most famously including Hand (1901), have argued that the appropriate remedy for adversarial bias (combined with inexpert juries) is increased reliance on court-appointed, nonpartisan experts.

in equilibrium. Thus, using court-appointed experts entails a trade-off: although these experts help judges obtain more information overall, thereby reducing the number of errors at trial, they weaken litigants' incentive to provide their expert information, thus undermining the adversarial nature of the current American legal system.

To the best of our knowledge, no prior theoretical research has examined the effect of court-appointed experts on litigants' behavior. Papers by Shin (1998) and Kim (2014a, 2017a), who compare the decentralized and centralized systems of information provision in the persuasion-game framework, are closely related to our research. In their papers, only the litigants provide information to the judges in the decentralized system while the judges themselves acquire information in the centralized system. In contrast, in our paper, we examine an integrated system in which both private and court-appointed experts are allowed in courtrooms.

Using a principal-agent model, Dewatripont and Tirole (1999), Palumbo (2001, 2006), Iossa and Palumbo (2007), Deffains and Demougin (2008), and Kim (2014b) examined whether decentralized systems can provide information to fact-finders at a lower cost. These models strongly support decentralized systems, showing that incentive constraints can be easily overcome by exploiting competition among agents. Demougin and Fluet (2008) and Emons and Fluet (2009b) indicated how expanding the role of judges in collecting information from litigants can improve decision-making. Froeb and Kobayashi (2001) examined the characteristics of the adversarial and inquisitorial systems, viewing them as estimators of the true state, and Parisi (2002) compared these two systems in a rent-seeking model.

The remainder of our paper is organized as follows. Section 2 outlines the details of the model studied in our paper. Section 3 presents our results from the preliminary analysis, followed by an equilibrium analysis in Section 4. Section 5 compares equilibrium outcomes across the two legal regimes studied, and Section 6 concludes. Proofs of propositions are provided in the Appendix.

2 Model

In this section, we develop a stylized game-theoretic model for litigation to investigate the effects of appointing a neutral expert to assist a judge. Three players participate in the litigation game: a plaintiff (P), a defendant (D), and a judge (J). J seeks to rule in favor of D if the true state is high, $t = h$, in which case J obtains a payoff of 1; if the true state is low, $t = l$, J seeks to rule in favor of P, in which case she obtains a payoff of 1. If J makes an incorrect decision and rules in favor of P under $t = h$ and vice versa, she obtains a payoff of 0. In contrast to J's preferences, both litigants want to win regardless of the true state: a litigant obtains a payoff of 1 if he wins and a payoff of 0 otherwise.

In the beginning of the litigation game, J believes that the true state is high with probability $\mu \equiv P(t = h)$. Thus, without further information, J rules in favor of P if $\mu < 1/2$

and in favor of D if $\mu \geq 1/2$. To influence J's decision, each litigant may consult an expert for evidence and then report this evidence to J, which is the current practice followed in adversarial litigation. In addition to the expert information provided by the litigants, J can also obtain information from a court-appointed expert, as proposed by many legal scholars and practitioners. To evaluate the effect of this proposal on the decision accuracy, we study two different litigation games and compare their equilibrium outcomes:

- Game-B: a litigation game with expert information provided only by the litigants
- Game-N: a litigation game with expert information provided by both the litigants and the court-appointed expert

where "B" indicates *biased* evidence supplied by the litigants and "N" indicates additional *neutral* evidence supplied by the court-appointed expert. As Game-B is analyzed in Kim (2017a), in this paper we focus on analyzing Game-N and comparing the equilibrium outcomes under the two litigation games.

Formally, a litigant i's expert, where $i \in \{P, D\}$, can observe hidden evidence $x_i \in \{H, L\}$ with probability $e \in (0, 1)$ where $P(H|h) = P(L|l) \equiv p > 1/2$. To eliminate trivial situations, we assume that a piece of evidence is influential in J's decision: $\mu < p$.[3] In this formulation, e can be interpreted as the expert's quality level because experts with a high value for e have a high chance of uncovering hidden evidence. Note that H can be considered "favorable" evidence for D and "unfavorable" evidence for P because, as clarified in the main analysis, if J observes H, she believes that $t = h$ is more likely to be the true state than before; L can similarly considered favorable evidence for P and unfavorable evidence for D.

In this model, we assume that all available experts have identical quality, that is, they have the same chance of retrieving hidden evidence during their investigations.[4] Moreover, to maintain tractability, we assume that the court-appointed expert's quality is equal to 1.

Game-N proceeds as follows:

- Period 1: The litigants simultaneously choose whether to consult an expert by paying costs c and obtain evidence
- Period 2: The litigants choose whether to report evidence truthfully to J
- Period 3: J observes reports from the litigants and the court-appointed expert, and makes a decision

[3] If $\mu \geq p$, J's decision is independent of the evidence supplied by the litigant.

[4] An alternative approach is to assume a pool of heterogeneous experts with a mean quality level e, where an expert is randomly contacted at the request of the litigants or the court. This approach is similar in spirit to the proposal by Robertson (2010). The result is the same under both approaches. See Sharif and Swank (2012) for an analysis of heterogeneity among litigants.

In period 1, the litigant $i \in \{P, D\}$ chooses $s_i \in \{0, 1\}$ where $s_i = 0$ means that the litigant i does not consult an expert and vice versa. If a litigant does not consult an expert, he obtains no evidence. If the litigant i consults an expert, he obtains a piece of verifiable evidence x_i when his expert finds it, but he obtains no evidence otherwise. In period 2, if a litigant has no evidence, he has nothing to present to J. If a litigant has a piece of evidence, he can truthfully present it to J, or suppress it and not present it to J. Thus, the event denoted by ϕ, in which a litigant does not present any evidence, may result from a lack of evidence or from evidence distortion. In period 3, after observing the report profile presented by the litigants and the court-appointed expert, J forms her posterior belief $\bar{\mu}$. Finally, J rules in favor of P if $\bar{\mu} < 1/2$ and in favor of D otherwise.

To control the number of notations and save space, we only report our main results for $\mu \geq 1/2$ and do not report the results for the other case, $\mu < 1/2$, because the latter result is symmetric to the former. As Game-N is a dynamic game with incomplete information, the appropriate equilibrium concept is perfect Bayesian equilibrium, which is simply referred to as equilibrium in this paper.

3 Preliminary Analysis

In this section, we investigate the ways in which J makes decisions according to the report profiles in period 3. Note that J must form a belief about the litigants' actions in period 1 when making a decision because she cannot directly observe them.

In period 2, each litigant truthfully reports only favorable evidence while suppressing unfavorable evidence because reporting unfavorable evidence reduces the litigant's chances of winning. Thus, when J makes a decision in period 3, eight report profiles are possible:

1. (L, ϕ, L): P wins
2. (ϕ, H, H): D wins
3. (L, ϕ, H): ambiguous
4. (ϕ, H, L): D wins
5. (L, H, L): P wins
6. (L, H, H): D wins
7. (ϕ, ϕ, L): ambiguous
8. (ϕ, ϕ, H): D wins

For instance, the first report profile, (L, ϕ, L), occurs if P reports L, D remains silent, and the court-appointed expert reports L. Considering this report profile in period 3, J has two pieces of "direct" evidence, one supplied by P and the other by her neutral expert. Thus, if J believes that D did not consult an expert in period 1, she must also believe that D has remained silent owing to a lack of information; therefore, J's posterior belief under this report profile is

$$\bar{\mu}(L, \phi, L) \equiv P(t = h|(L, \phi, L)) = \frac{\mu(1-p)^2}{\mu(1-p)^2 + (1-\mu)p^2} < \frac{1}{2}$$

which induces J to rule in favor of P.

However, a piece of "indirect" evidence could emerge in this report profile: if J believes that D consulted an expert in period 1, J could also believe that D is suppressing unfavorable evidence (i.e., L), thus providing J with additional information about the true state. In this case, J's posterior belief is

$$\bar{\mu}(L, \phi, L) = \frac{\mu e(1-p)(1-ep)(1-p)}{\mu e(1-p)(1-ep)(1-p) + (1-\mu)ep(1-e+ep)p} < \frac{1}{2}$$

which also induces J to rule in favor of P. Thus, regardless of J's belief about D's action in period 1, J rules in favor of P under the report profile (L, ϕ, L). Other report profiles and associated decisions by J can be similarly understood.

In contrast to other report profiles, we cannot determine J's decisions under (L, ϕ, H) and (ϕ, ϕ, L) because J's beliefs about the litigants' actions in period 1 are crucial in these two report profiles. For example, consider the first *ambiguous* situation, (L, ϕ, H). On one hand, if J believes that D did not consult an expert, her posterior belief is

$$\bar{\mu}(L, \phi, H) = \mu \geq \frac{1}{2}$$

which holds because no indirect evidence can be obtained from D's silence and two conflicting pieces of evidence nullify each other in J's assessment about the true state. Thus, J rules in favor of D. On the other hand, if J believes that D consulted an expert in period 1, her posterior belief is

$$\bar{\mu}(L, \phi, H) = \frac{\mu(1-ep)}{\mu(1-ep) + (1-\mu)(1-e+ep)}$$

which could be larger or smaller than 1/2. Thus, J could rule in favor of either litigant, depending on the specific litigation environment. This finding indicates that in these ambiguous situations, J's decision crucially depends on her own beliefs about the litigants' actions in period 1. Therefore, J's beliefs influence the *burden of proof* faced by the litigants: if J forms an unfavorable belief about a litigant's action in period 1, that litigant will require stronger evidence, either direct or indirect, to induce J to rule in his favor. Thus, for the equilibrium analysis in the next section, it is convenient to provide the following definitions:

Definition 1. *The burden of proof (henceforth BOP) is said to be on the litigant $i \in \{P, D\}$ if i loses under all ambiguous situations. BOP is said to be shared between P and D if a litigant loses under an ambiguous situation but wins under the other.*

Definition 2. *P-equilibrium (D-equilibrium) is an equilibrium in which BOP is on P (D). S-equilibrium is an equilibrium in which BOP is shared between the two litigants.*

4 Equilibrium Analysis

In this section, we find the equilibria in Game-N. To this end, first suppose BOP falls on P. According to Definitions 1 and 2, this means that P loses under both ambiguous situations. Under our assumed BOP allocation, we first find players' equilibrium strategies and then verify whether our supposed BOP allocation is indeed consistent with players' equilibrium strategies. If BOP falls on P, the possible report profiles and J's decisions in period 3 are as follows:

1. (L, ϕ, L): P wins
2. (ϕ, H, H): D wins
3. (L, ϕ, H): D wins
4. (ϕ, H, L): D wins
5. (L, H, L): P wins
6. (L, H, H): D wins
7. (ϕ, ϕ, L): D wins
8. (ϕ, ϕ, H): D wins

In period 1, the litigants simultaneously choose whether to consult an expert while anticipating J's decision under the report profiles above. It is convenient to define the following function:

$$\begin{aligned}\kappa(s_P, s_D) \quad &\equiv \quad s_P \cdot \{\mu e(1-p)(1-ep \cdot s_D)(1-p) + (1-\mu)ep(1-e(1-p)s_D)p \\ &\qquad\qquad +\mu e(1-p)ep \cdot s_D(1-p) + (1-\mu)ep \cdot e(1-p)s_D \cdot p\}\end{aligned}$$

where $s_i = 1$ if the litigant $i \in \{P, D\}$ consults an expert and $s_i = 0$ otherwise.

The first part inside the parentheses is the probability of the report profile (L, ϕ, L) under $t = h$: $e(1-p)$ is the probability that P reports L,[5] $1 - ep \cdot s_D$ is the probability that D

[5] Here, we assume $s_P = 1$. If $s_P = 0$, this probability is 0 because s_P is multiplied to the expression.

remains silent,[6] and $1-p$ is the probability that J's neutral expert reports L. The second part can be similarly understood as it represents the probability of the report profile (L, ϕ, L) under $t = l$. The third and fourth parts represent the probability that the report profile (L, H, L) is realized under $t = h$ and $t = l$, respectively. Noting that P only wins under the two report profiles (L, ϕ, L) and (L, H, L), this function $\kappa(s_P, s_D)$ provides us with P's winning probability. Accordingly, D's winning probability is given by $1 - \kappa(s_P, s_D)$ because winnings by P and D are complementary events.

A few comments about κ are in order. First, observe $\kappa(0, s_D) = 0$ for all $s_D \in \{0, 1\}$. This is because P cannot win unless he can present favorable evidence for his cause under the supposed BOP. Second, we have $\kappa(1, 1) = \kappa(1, 0)$. In other words, when P consults an expert, D's action regarding expert choice cannot influence the winning probabilities of both litigants. This is because P wins only under $(L, \cdot, L)$, in which case D cannot counteract the two pieces of unfavorable evidence and consequently D always loses regardless of his report.

From these two comments, we can easily conclude that D will not consult an expert: because he cannot influence the winning probabilities by consulting an expert, he will not want to incur the expense of obtaining expert information.[7] Therefore, it remains to determine the conditions under which P consults an expert. If P does not consult an expert, his winning probability is $\kappa(0, 0) = 0$, and therefore P's expected payoff from consulting no expert is 0. If he consults an expert, his winning probability is $\kappa(1, 0)$, and therefore his expected payoff from consulting an expert is $\kappa(1, 0) - c$. Thus, P consults an expert if and only if

$$c \leq \kappa(1, 0).$$

Thus, we have two possibilities in period 1: neither litigant consults an expert if the cost of expert information is high, $\kappa(1, 0) < c$, and otherwise only P consults an expert, $c \leq \kappa(1, 0)$.

It remains to verify whether these behaviors by the litigants are consistent with our assumed BOP, and thus consisent with J's beliefs in ambiguous situations, in equilibrium. First, suppose $c \leq \kappa(1, 0)$, in which case only P is willing to consult an expert. Under the first ambiguous situation, (L, ϕ, H), J's posterior belief should be identical to her prior belief because (i) the two pieces of conflicting evidence nullify each other, and (ii) J cannot obtain any indirect evidence from D's silence because she knows that D did not consult any expert. Therefore, we have $\bar{\mu}(L, \phi, H) = \mu \geq \frac{1}{2}$, inducing J to rule in favor of D, which is consistent with our supposed BOP under (L, ϕ, H). Under the second ambiguous situation, (ϕ, ϕ, L), J's

[6] If D does not consult an expert (i.e., $s_D = 0$), he is silent with probability 1. If D consults an expert, he is silent unless his expert finds H, which gives us probability $1 - ep$.

[7] We obtain this result only for P-equilibrium in which BOP is on P. As observed in Proposition 1, D has an incentive to consult an expert if the cost is small under other types of equilibria.

posterior belief is given by

$$\bar{\mu}(\phi, \phi, L) = \frac{\mu(1-e+ep)(1-p)}{\mu(1-e+ep)(1-p) + (1-\mu)(1-ep)p}.$$

To be consistent with our supposed BOP, this posterior belief must be larger than 1/2. One can easily verify that this posterior belief is (i) increasing in e, getting close to μ as e gets close to 1, and (ii) increasing in μ, getting close to $(1-e+ep)/(2-e) > 1/2$ as μ gets close to p. Therefore $\bar{\mu}(\phi, \phi, L)$ is consistent with our supposed BOP if e is close to 1 or μ is close to p. We conclude that if $c \leq \kappa(1, 0)$, P-equilibrium in which only P consults an expert exists when e or μ is large.

Now suppose $\kappa(1, 0) < c$, in which case neither litigant consults an expert. This behavior by litigants is not consistent with our supposed BOP because under the second ambiguous situation, J's posterior belief is given by

$$\bar{\mu}(\phi, \phi, L) = \frac{\mu(1-p)}{\mu(1-p) + (1-\mu)p} < \frac{1}{2}$$

which leads J to rule in favor of P, contradicting our supposed BOP. Therefore, if $\kappa(1, 0) < c$, there is no P-equilibrium. These results are summarized in the first part of Proposition 1 below, where $\bar{c}_P^N \equiv \kappa(1, 0)$. Proofs for the existence of other equilibria are analogous to that for P-equilibrium (although these proofs are much more involved), and therefore they are included in the Appendix.

Proposition 1. (i) *There exists* $\bar{c}_P^N > 0$ *such that the following is true:*

- $\bar{c}_P^N < c$*: P-equilibrium does not exist*
- $c \leq \bar{c}_P^N$*: P-equilibrium (with* $s_P = 1$ *and* $s_D = 0$*) exists if* e *or* μ *is large*

(ii) *There exist* $\underline{c}_D^N$ *and* $\bar{c}_D^N$ *such that* $0 < \underline{c}_D^N < \bar{c}_D^N$ *for which the following is true:*

- $\bar{c}_D^N < c$*: D-equilibrium (with* $s_P = s_D = 0$*) exists*
- $\underline{c}_D^N < c \leq \bar{c}_D^N$*: D-equilibrium (with* $s_P = 0$ *and* $s_D = 1$*) exists*
- $c \leq \underline{c}_D^N$*: D-equilibrium (with* $s_P = s_D = 1$*) exists if* μ *is small or* e *is large.*

(iii) *There exist* $\underline{c}_S^N$ *and* $\bar{c}_S^N$ *such that* $0 < \underline{c}_S^N < \bar{c}_S^N$ *for which the following is true:*

- $\bar{c}_S^N < c$*: S-equilibrium (with* $s_P = s_D = 0$*) exists*
- $\underline{c}_S^N < c \leq \bar{c}_S^N$*: S-equilibrium (with* $s_P = 0$ *and* $s_D = 1$*) exists*
- $c \leq \underline{c}_S^N$*: S-equilibrium (with* $s_P = s_D = 1$*) exists if* μ *is large or* e *is small.*

Proof. See Appendix A.1. □

A few remarks about Proposition 1 are in order. The first immediate observation is the multiplicity of equilibria in Game-N. As J cannot observe the litigants' actions in period 1, she must form a belief about them. If J forms an unfavorable belief toward D, believing that only D consulted an expert in period 1, it increases the degree of "skepticism" about D's silence. This requires stronger evidence favoring D to ensure that D wins, inducing D to consult an expert for evidence and fulfilling J's belief in equilibrium. Thus, in a persuasion game with information acquisition, the issue of the multiplicity of equilibria is unavoidable.

Compared to other types of equilibria, the condition for the existence of P-equilibrium is very stringent.[8] This is because the ambiguous situations under the supposed prior belief ($\mu \geq 1/2$) barely admit BOP on P. To clarify this point, consider an ambiguous situation (ϕ, ϕ, L). The direct evidence L provides a strong support for P; therefore, to rule against P in this situation, J requires strong indirect evidence in favor of D, which will have to be obtained from the silence of both litigants. However, this is difficult because even if J believes that only P consulted an expert, the strength of the indirect evidence against P is weaker than that of the direct evidence in favor of P (because the probability that P is hiding H is less than 1).

The other two types of equilibria, D-equilibrium and S-equilibrium, have similar equilibrium structures. If the cost of consulting an expert is high, both equilibria always exist, in which neither litigant consults an expert. As the cost decreases, the demand for expert information increases. If the cost is small, both litigants have an incentive to consult experts in D-equilibrium and S-equilibrium, and one of these two equilibria may not exist. To understand this possibility, first consider an ambiguous situation (ϕ, ϕ, L). If both litigants consult an expert, the indirect evidence from each litigant's silence nullifies that of the other, thereby leaving J with only the direct evidence L. Thus, J rules in favor of P under this ambiguous situation. Accordingly, the existence of these two equilibria crucially depends on the identity of the winning party in the other ambiguous situation (L, ϕ, H). As the two pieces of direct evidence nullify each other, the indirect evidence from D's silence is crucial, which "lowers" J's posterior belief (because D could be hiding L). On one hand, if this posterior updating is strong enough to drop J's posterior belief below the decision threshold of $1/2$, J will rule in favor of P under (L, ϕ, H). Then, as BOP is on D (i.e., D loses in both ambiguous situations), D-equilibrium exists in this case while S-equilibrium does not exist. On the other hand, if the posterior updating is not strong enough, $\bar{\mu} \geq 1/2$, we obtain the opposite result: D-equilibrium does not exist while S-equilibrium exists.

[8]We obtain this result under the assumption $\mu \geq 1/2$. If $\mu < 1/2$, we obtain an opposite result, thereby finding a stringent condition for the existence of D-equilibrium. As we mentioned in Section 2, we do not report the results for $\mu < 1/2$ so as to keep the number of notations in check and to save space.

The preceding discussion implies that an equilibrium always exists in Game-N. For instance, if we suppose that S-equilibrium does not exist for the low-cost range, D-equilibrium must exist when the cost is small; therefore, D-equilibrium always exists regardless of the magnitude of the cost.

In the next section, we present the results from Game-B, which is analyzed in Kim (2017a), and compare the equilibrium outcomes from Game-N and Game-B.

5 Comparison of Game-N and Game-B

5.1 Equilibria in Game-B

Game-B was analyzed by Kim (2017a), and we report his results here as a lemma:[9]

Lemma 1. *(i) There exist* $\underline{c}_P^B$ *and* $\bar{c}_P^B$ *such that* $0 < \underline{c}_P^B < \bar{c}_P^B$ *for which the following is true:*

- $\bar{c}_P^B < c$*: P-equilibrium (with* $s_P = s_D = 0$*) exists*
- $\underline{c}_P^B < c \leq \bar{c}_P^B$*: P-equilibrium (with* $s_P = 1$ *and* $s_D = 0$*) exists*
- $c \leq \underline{c}_P^B$*: P-equilibrium (with* $s_P = s_D = 1$*) exists*

(ii) There exists $\bar{c}_D^B > 0$ *such that the following is true:*

- $\bar{c}_D^B < c$*: D-equilibrium does not exist*
- $c \leq \bar{c}_D^B$*: D-equilibrium (with* $s_P = 0$ *and* $s_D = 1$*) exists if* μ *is small or* e *is large.*

As Game-B does not include a court-appointed expert, four report profiles are possible in period 3:

1. (L, H): D wins
2. (L, ϕ): P wins
3. (ϕ, H): D wins
4. (ϕ, ϕ): ambiguous

The first report profile is realized if P reports L and D reports H, in which case J rules in favor of D because her posterior belief is equal to $\mu \geq 1/2$ owing to the existence of two conflicting pieces of evidence. The second and third report profiles, with their associated decisions, can be similarly understood. The only ambiguous situation is when J observes the fourth report profile, in which case J's posterior belief depends on her beliefs about the litigants' actions in period 1. As only one ambiguous situation exists and either P or D wins in that situation, two types of equilibria exist under Game-B: P-equilibrium and D-equilibrium.

[9] We refer readers to Kim (2017a) for more details.

5.2 The Incentive Effect of Court-Appointed Experts

In this subsection, we examine how the existence of the court-appointed expert influences the litigants' incentive to supply evidence to J. The following proposition demonstrates that expert information is utilized in Game-B more often than in Game-N.

Proposition 2. $\max\{\bar{c}_P^N, \bar{c}_D^N, \bar{c}_S^N\} < \min\{\bar{c}_D^B, \bar{c}_P^B\}$

Proof. See Appendix A.2. □

To understand this result, observe that $\bar{c}_P^N$, $\bar{c}_D^N$ and $\bar{c}_S^N$ are the cost thresholds for the equilibria of Game-N such that neither litigant utilizes expert information if the cost is beyond the threshold in each equilibrium. Thus, for instance, in the case of D-equilibrium, if the cost is larger than $\bar{c}_D^N$, D-equilibrium exists and neither litigant consults an expert in that equilibrium. Likewise, the threshold from Game-B, $\bar{c}_P^B$, is such that neither litigant consults an expert in P-equilibrium of Game-B if the cost is larger than $\bar{c}_P^B$.

Proposition 2 implies that if the cost of consulting an expert lies between $\max\{\bar{c}_P^N, \bar{c}_D^N, \bar{c}_S^N\}$ and $\bar{c}_P^B$, neither litigant will consult an expert in any equilibrium of Game-N while at least one litigant will consult an expert in P-equilibrium in Game-B. As P-equilibrium always exists in Game-B, this result demonstrates that expert information is utilized in Game-B for a wider range of litigation environments.

This result shows that the presence of court-appointed experts weakens the litigants' incentive to utilize expert information. In Game-B, J is uninformed and must rely on the litigants to provide information to make a decision. In contrast, in Game-N, J has access to an additional piece of evidence supplied by the court-appointed expert, and the litigants cannot observe this piece of information when they make their own choices. Therefore, the litigants expect their evidence to have less influence on J's decision in Game-N than in Game-B, thus losing their incentive to seek evidence in their favor. This finding thus shows that J's private knowledge regarding the dispute could demotivate the litigants in their information acquisition activities.

To the best of our knowledge, the effect of a decision-maker's private information on agents' incentive to acquire information has not been studied in the persuasion-game literature. Related studies in the cheap-talk setting, in which information is not verifiable, include papers by Chen (2012), Lai (2014), Moreno de Barreda (2010), and Shimizu and Ishida (2016); these papers focus on the effect of a decision-maker's private information on an informed agent's incentive to communicate his information to the decision-maker, assuming that the agent already possesses information at the beginning of the game.[10] They show that the decision-maker's private information could impede communication with the informed agent.

[10] For experimental studies of cheap talk games, see Bonroy et al. (2017) and Cai and Wang (2006) among others.

In contrast, Proposition 2 demonstrates that the decision-maker's private information could impede the agent's information acquisition, thus leading to less information being transmitted to the decision-maker in equilibrium.

As the current American legal system is inherently adversarial, with the litigating parties having the responsibility of evidence collection, the loss of private incentive to provide evidence due to the presence of a court-appointed expert could be regarded as a serious threat to the system. This finding could rationalize, within a standard economic model of litigation, judges' reluctance to invoke Federal Rule of Evidence 706, which states that the court may select and appoint its own expert witnesses. As noted by Cecil and Willging (1994), who outline surveys and interviews with federal judges regarding their use of, and attitudes toward, court-appointed experts, Rule 706 has been infrequently invoked since its enactment because, among other reasons, many judges have been reluctant to appoint experts out of concern that doing so would interfere with the adversarial process.

However, although the presence of the court-appointed expert could induce litigants to provide evidence less often, J could make a more precise decision because she could obtain more information overall, with evidence from both the litigants and the court-appointed expert. To investigate this issue, we formally define the measure of decision errors as follows:

$$E = \mu\alpha + (1-\mu)\beta$$

where $\alpha = P(\text{P wins}|t = h)$ is the probability that P wins despite $t = h$, and $\beta = P(\text{D wins}|t = l)$ is the probability that D wins despite $t = l$. Note that D's winning under $t = l$ and P's winning under $t = h$ are clearly incorrect decisions. In particular, considering $t = h$ as the "null hypothesis" and $t = l$ as the "alternative hypothesis," α and β can be interpreted as type I and type II errors, respectively. Thus, according to this interpretation, the above measure is the average of the two types of errors. The following proposition demonstrates that E^N, the decision error from an equilibrium of Game-N, is always smaller than E^B, the decision error from an equilibrium of Game-B, for all values of the cost parameter and for all possible pairs of equilibria from the two games.

Proposition 3. *For all $c > 0$ and for all possible pairs of equilibria from the two games, we have $E^N \leq E^B$.*

Proof. See Appendix A.3. □

Intuitively, to find a situation in which Game-B generates fewer errors than Game-N, we need to consider a value of cost at which no expert is hired by either litigant in an equilibrium of Game-N but two experts are hired by the litigants in an equilibrium of Game-B. As J can always consult the court-appointed expert in Game-N, she will have at least one piece of neutral evidence for her decision. Thus, a necessary condition for generating more information in Game-B is that the litigants must provide two pieces of biased information to J. Proposition 3 shows that there is no value of cost under which this is true in our framework, and that the error costs cannot be larger in Game-N for the entire cost range.

In our analysis, we abstracted from the cost of utilizing court-appointed experts for simplicity. In general, society may be concerned with expert costs when court-appointed experts are utilized at courts. To this end, consider a social planner who seeks to minimize the social cost composed of error costs and expert costs:

$$SC = E + C$$

where E is error costs and C is expert costs. Then, Proposition 3 tells us that he faces a trade-off in choosing between Game-N and Game-B because allowing court-appointed experts reduces error costs only at the expense of additional expert costs incurred to utilize court-appointed experts. Thus, the social planner would choose Game-N if the benefit of reduced error costs outweighs the cost of additional expert costs, and vice versa. To study this formally, suppose in period 0, the social planner chooses whether to allow court-appointed experts at the courtroom. Thus, if court-appointed experts are allowed, Game-N follows in period 1; otherwise, Game-B follows in period 1. Anticipating the equilibrium outcomes from the two subgames, the social planner would make a decision to minimize the social cost. One immidiate concern in this exercise is that there are many equilibria in both subgames. For simplicity, let us assume that the social planner anticipates P-equilibrium from Game-B and D-equilibrium from Game-N, and consider the parameter values guaranteeing the existence of both equilibria; we can make a similar observation for other pairs of equilibria, so we focus on this pair of equilibria for brevity.

Proposition 4. *Suppose the social planner anticipates P-equilibrium from Game-B and D-equilibrium from Game-N.*

- *Case 1:* $\underline{c}_D^N \leq \underline{c}_P^B \leq \bar{c}_D^N < \bar{c}_P^B$
  - *If* $c \in (0, \underline{c}_D^N]$, *the social planner allows court-appointed experts in period 0 if*

$$c_J \leq (p - \mu)(1 - e + 2e^2 p(1 - p))$$

  - *If* $c \in (\underline{c}_D^N, \underline{c}_P^B]$, *the social planner allows court-appointed experts in period 0 if*

$$c_J \leq (1 - e)(p(1 + e(1 - p)(2\mu - 1)) - \mu) + c$$

  - *If* $c \in (\underline{c}_P^B, \bar{c}_D^N]$, *the social planner allows court-appointed experts in period 0 if*

$$c_J \leq \mu(1 - p)(e - 1 + ep) + (1 - \mu)(1 - ep - (1 + ep)(1 - p))$$

- *If* $c \in (\bar{c}_D^N, \bar{c}_P^B]$*, the social planner allows court-appointed experts in period 0 if*

$$c_J \leq (1-e)(p-\mu) + c$$

- *If* $c \in (\bar{c}_P^B, \infty)$*, the social planner allows court-appointed experts in period 0 if*

$$c_J \leq p - \mu$$

- *Case 2:* $\underline{c}_P^B < \underline{c}_D^N \leq \bar{c}_D^N < \bar{c}_P^B$
  - *If* $c \in (0, \underline{c}_P^B]$*, the social planner allows court-appointed experts in period 0 if*

$$c_J \leq (p-\mu)(1-e+2e^2p(1-p))$$

  - *If* $c \in (\underline{c}_P^B, \underline{c}_D^N]$*, the social planner allows court-appointed experts in period 0 if*

$$c_J \leq (1-e)(p-\mu) + c$$

  - *If* $c \in (\underline{c}_D^N, \bar{c}_D^N]$*, the social planner allows court-appointed experts in period 0 if*

$$c_J \leq \mu(1-p)(e-1+ep) + (1-\mu)(1-ep-(1+ep)(1-p))$$

  - *If* $c \in (\bar{c}_D^N, \bar{c}_P^B]$*, the social planner allows court-appointed experts in period 0 if*

$$c_J \leq (1-e)(p-\mu) + c$$

  - *If* $c \in (\bar{c}_P^B, \infty)$*, the social planner allows court-appointed experts in period 0 if*

$$c_J \leq p - \mu$$

Proof. See Appendix A.4. □

These results show that employing court-appointed experts in a standard litigation game entails a trade-off. While it helps the judge to obtain more information overall, thereby reducing the number of mistakes at trial, it weakens litigants' incentive to supply their own expert information, thus undermining the adversarial nature of the current American legal system.

This trade-off is related to the adversarial vs. inquisitorial debate. Since early contributions to this debate by Posner (1988, 1999) and Tullock (1975, 1980, 1988), the literature has extensively examined the relative merits of each system.[11] In particular, one of the main in-

[11] See Milgrom and Roberts (1986), Froeb and Kobayashi (1996), Shin (1998), Froeb and Kobayashi (2001),

sights from these works, based on economic models, is that the adversarial system is superior to the inquisitorial system for generating information using the initiatives of the interested parties; however, it is inferior for transmitting information from the parties to the judge due to evidence distortion. One caveat in these works is that researchers have usually compared the two systems in their pure forms: only the litigants provide information to the judges in the adversarial system while the judges themselves acquire information in the inquisitorial system. Our results show that in the mixed system, where both private and court-appointed experts are allowed in courtrooms, enhancing the inquisitorial component of the legal system generates *more* information for the court's decision-making at the expense of the litigants' information.

Our results are also related to the debate about "managerial" judges, a term reputedly coined by Resnik (1982) who used it to "describe a judge's hands-on supervision of cases from the outset, using various procedural tools to speed the process of dispute resolution and encourage settlement" (Thornburg (2010)).[12] Scholars have long debated why we should support or condemn judges' managerial role. On one hand, the extensive discretion of judges could expedite the dispute resolution process, encourage settlement, and ensure fairness, which are only a few of the many benefits suggested by the proponents of judges' managerial role. On the other hand, the outcomes of disputes could become unpredictable as individual judges assume more dominant roles; a managerial judge's own conscious or unconscious biases could tilt the ground in favor of one party over the other; and plaintiffs with similar merits could obtain varying damages from case to case, thus generating significant social costs. We note yet another cost of managerial judges: in case of information provision, court initiatives could *crowd out* the litigants' initiatives in the fact-finding procedures. Thus, as society develops judges' managerial roles in processing the necessary information in a dispute, one could observe the litigants becoming more passive, which could consequently undo the presumed benefits of having managerial judges.

6 Concluding Remarks

This paper examined litigants' incentive problem in cases where judges seek the advice of court-appointed experts who directly report to judges. Our results revealed that although impartial advisors appointed by the court help judges obtain more information overall and thus reduce the number of errors in a trial, they weaken litigants' incentives to supply expert information, which undermines the adversarial nature of the current American legal system.

In our persuasion-game framework, litigants' disclosure behavior is the same regardless

Parisi (2002), Demougin and Fluet (2008), Emons and Fluet (2009a,b), and Kim (2014a, 2017a) for this line of research.

[12] See also Elliott (1986) and Peterson (1995) among others.

of the presence of a court-appointed expert: both litigants reveal favorable evidence while suppressing unfavorable evidence. In reality, when a judge appoints a court advisor, litigants may respond by altering their disclosure behavior. On one hand, they may disclose more information out of fear of adverse consequences following the judge's cross-examination of both their evidence and that of the court advisor. For instance, a judge may exclude the plaintiff's expert testimony under *Daubert* if the proffered damages are very different from those reported by the court advisors.[13] Thus, although the litigants may have a weaker incentive to collect information when judges appoint neutral advisors, a judge could obtain more information overall from the litigants if they disclose more information than they would in the absence of a neutral advisor. In contrast, the litigants could respond by disclosing less information. If a litigant considers his case to be weak, he may believe that the court-appointed experts will supply the fact-finder with evidence unfavorable to him; this litigant, therefore, requires stronger evidence to win, which could increase his incentive to distort evidence. These effects may result in additional benefits and costs that have not been captured in our formulation.

In our model, the role of court-appointed experts is to provide judges with an additional piece of evidence. Rather than using court-appointed experts as sources of information, Erichson (1998) and Bernstein (2008) have suggested that judges use them as advisors on issues such as the admissibility of scientific evidence, which could also benefit the fact-finder if information is not verifiable. Such advisory roles of a court-appointed expert could be particularly relevant for jury trials, which have been criticized by many legal scholars and practitioners, especially when those cases involve complex scientific or statistical evidence proffered by experts. The primary reason behind this is, as the argument goes, lay juries are ill-prepared to evaluate such complex evidence.[14] In such cases, a court-appointed expert can help the fact-finder evaluate complex evidence and thereby more accurately assess the underlying dispute, which could be another benefit of appointing court-appointed experts.

In practice, although we assume that court-appointed experts are unbiased and neutral in our theoretical analysis, requiring a judge to appoint her own neutral experts is easier said than

[13] After a series of important decisions—*Daubert v. Merrell Dow Pharms., Inc.*, 509 U.S. 579 (1993), *Gen. Elec. Co. v. Joiner*, 522 U.S. 136 (1997), and *Kumho Tire Co., Ltd. v. Carmichael*, 526 U.S. 137 (1999)—the Supreme Court set a strict standard for the admissibility of expert testimony. The Federal Rule of Evidence 702 was eventually amended in 2000, requiring experts to pass a stringent reliability test, often called the *Daubert* test, to qualify for providing their testimony in court. Rule 702 stipulates that expert testimony that would otherwise benefit the jury is admissible only when (*i*) the testimony is based on sufficient facts or data, (*ii*) the testimony is the product of reliable principles and methods, and (*iii*) the witness has applied the principles and methods reliably to the facts of the case.

[14] See, for instance, Kalven and Zeisel (1966) and Simon (1975) for the controversy over the merits of using lay juries. In *Skidmore v. Baltimore and Ohio R.R.*, 116 F.2d 54 (1947), Judge Jerome Frank wrote: "While the jury can contribute nothing of value so far as the law is concerned, it has infinite capacity for mischief, for twelve men can easily misunderstand more law in a minute than the judge can explain in an hour." Dean Griswold of Harvard Law School argued (Guinther, 1988): "The jury trial at best is the apotheosis of the amateur. Why should anyone think that 12 persons brought in from the street, selected in various ways, for their lack of general ability, should have any special capacity for deciding controversies between persons?"

done: these experts themselves could hold biased views about the dispute, thereby introducing new biases into the system; a judge herself may have biases that could influence her choice of experts; and the expert selection process could favor a particular group of experts over others, thereby supplying the fact-finder with biased rather than unbiased voice. Potential biases introduced through these channels could reduce the value of using court-appointed experts. Moreover, if the fact-finder, especially in case of lay juries, mistakenly believes that a court-appointed expert's biased conclusion is unbiased and neutral, she could end up with more mistakes after consulting such an expert. It could be an interesting avenue for future research to theoretically investigate these issues in a formal model.

Finally, to maintain the model's tractability in our analysis, we assume that the court-appointed expert's quality is equal to 1 while that of the litigants' experts is less than 1. If we relax this assumption, that is, we assume that the court-appointed expert's quality is also less than 1, judges could be conceived to make mistakes more often in certain cases when employing court-appointed experts. Intuitively, this situation could arise in an extended formulation when the incentive effect is large. The now-less-reliable additional information from the court-appointed expert could be more than compensated for by the loss of information occurring due to reduced incentives for litigants to seek and present evidence. In such cases, hiring a court-appointed expert would be detrimental to the justice system because it would not only undermine the adversarial nature of the legal system but also decrease the accuracy of the final decisions made. Studying this extended formulation is beyond the scope of our current paper and we therefore leave it to future research.

A Appendix

A.1 Proof of Proposition 1

The proof of Proposition 1 consists of two steps. First, we find the litigants' equilibrium strategies, taking J's equilibrium belief as given (i.e., assuming a particular BOP assignment). Second, we verify whether the litigants' equilibrium strategies are consistent with J's equilibrium belief.

Before proceeding, note that there are 8 possible report profiles in period 3:

1. (L, ϕ, L): P wins
2. (ϕ, H, H): D wins
3. (L, ϕ, H): ambiguous
4. (ϕ, H, L): D wins
5. (L, H, L): P wins

6. (L, H, H): D wins

7. (ϕ, ϕ, L): ambiguous

8. (ϕ, ϕ, H): D wins

A.1.1 The Existence of D-equilibrium

Consider a case in which BOP falls on D. That is, suppose P wins under both ambiguous report profiles, (L, ϕ, H) and (ϕ, ϕ, L). Then P's payoff (i.e., probability of winning), denoted by κ^D, is given by[15]

$$\kappa^D(s_P, s_D) = u_P(L, \phi, L) + u_P(L, \phi, H) + u_P(L, H, L) + u_P(\phi, \phi, L)$$

where each term is given by

$$\begin{aligned}
u_P(L, \phi, L) &= \mu\{s_P \cdot e(1-p)\}\{(1-s_D) + s_D(1-e+e(1-p))\}(1-p) \\
&\quad +(1-\mu)\{s_P \cdot ep\}\{(1-s_D) + s_D(1-e+ep)\}p \\
u_P(L, \phi, H) &= \mu\{s_P \cdot e(1-p)\}\{(1-s_D) + s_D(1-e+e(1-p))\}p \\
&\quad +(1-\mu)\{s_P \cdot ep\}\{(1-s_D) + s_D(1-e+ep)\}(1-p) \\
u_P(L, H, L) &= \mu\{s_P \cdot e(1-p)\}\{s_D \cdot ep\}(1-p) \\
&\quad +(1-\mu)\{s_P \cdot ep\}\{s_D \cdot e(1-p)\}p \\
u_P(\phi, \phi, L) &= \mu\{(1-s_P) + s_P(1-e+ep)\}\{(1-s_D) + s_D(1-e+e(1-p))\}(1-p) \\
&\quad +(1-\mu)\{(1-s_P) + s_P(1-e+e(1-p))\}\{(1-s_D) + s_D(1-e+ep)\}p
\end{aligned}$$

Given D's decision to consult an expert or not (i.e., s_D), P consults if and only if $c \leq \kappa^D(1, s_D) - \kappa^D(0, s_D)$. That is, P consults an expert if his marginal gain from hiring an expert is higher than the marginal cost. Since D's winning is a complementary event to P's winning, D's payoff is $1 - \kappa^D(s_P, s_D)$, and D consults an expert if and only if $c \leq (1 - \kappa^D(s_P, 1)) - (1 - \kappa^D(s_P, 0)) = \kappa^D(s_P, 0) - \kappa^D(s_P, 1)$.

Let us find the litigants' equilibrium strategies in Pretrial Stage. To simplify the notations,

[15] The superscript D in κ^D indicates that this probability is calculated when BOP is on D.

we define the following quantities:[16]

$$
\begin{aligned}
c_0^D &\equiv \kappa^D(0,0) - \kappa^D(0,1) = \mu \cdot e(1-p)p + (1-\mu) \cdot ep(1-p) \\
c_1^D &\equiv \kappa^D(1,0) - \kappa^D(0,0) = \mu \cdot e(1-p)p + (1-\mu) \cdot ep(1-p) \\
c_2^D &\equiv \kappa^D(1,0) - \kappa^D(1,1) = \mu \cdot e(1-p)p\{1-e+2ep\} + (1-\mu) \cdot e(1-p)p\{1-e+2e(1-p)\} \\
c_3^D &\equiv \kappa^D(1,1) - \kappa^D(0,1) = \mu \cdot e(1-p)p\{1-e+2e(1-p)\} + (1-\mu) \cdot ep(1-p)\{1-e+2ep\}
\end{aligned}
$$

The following lemma demonstrates the litigants' equilibrium strategies given the BOP assignment.

Lemma 2. *Suppose that BOP is on D in equilibrium. Then, the following are the litigants' equilibrium strategies in Pretrial Stage:*

- *If $\bar{c}_D^N < c$, no litigant consults an expert*
- *If $\underline{c}_D^N < c \leq \bar{c}_D^N$, only D consults an expert*
- *If $c \leq \underline{c}_D^N$, both litigants consult an expert*

where $\bar{c}_D^N \equiv c_0^D$ and $\underline{c}_D^N \equiv c_3^D$.

Proof. Observe that we have

$$c_3^D \leq c_0^D = c_1^D \leq c_2^D$$

because $c_2^D - c_1^D = c_0^D - c_3^D = epe(1-p)(2\mu-1)(2p-1) \geq 0$ since $e > 0$, $p > \frac{1}{2}$, and $\mu \geq \frac{1}{2}$.

A litigant hires an expert for testimony only when the net benefit from it is greater than the cost incurred. If $c > c_2^D$, it is clear that no one consults. If $c \in (c_0^D, c_2^D]$, P has no incentive to consult an expert, and therefore D also does not consult an expert. If $c \in (c_3^D, c_0^D]$, only D consults an expert, in which case P does not consult an expert because $c > c_3^D$. Finally, if $c \leq c_3^D$, both litigants consult an expert because the cost is smaller than the net benefits for both litigants. □

Next, let us examine whether the litigants' equilibrium strategies from the above lemma are consistent with BOP on D:

- Suppose $\bar{c}_D^N < c$ so that no litigants consult. Then, we have

$$\bar{\mu}(\phi, \phi, L) = \frac{\mu(1-p)}{\mu(1-p) + (1-\mu)p} < \frac{1}{2}$$

[16] The meaning of these quantities are:

- c_0^D is D's net benefit from expert advice when P does not consult an expert
- c_1^D is P's net benefit from expert advice when D does not consult an expert
- c_2^D is D's net benefit from expert advice when P consults an expert
- c_3^D is P's net benefit from expert advice when D consults an expert.

- Suppose $\underline{c}_D^N < c \leq \bar{c}_D^N$ so that only D consults. Then, we have

$$\bar{\mu}(\phi, \phi, L) = \frac{\mu(1-ep)(1-p)}{\mu(1-ep)(1-p) + (1-\mu)(1-e(1-p))p} < \frac{1}{2}$$

- Suppose $c \leq \underline{c}_D^N$ so that both consult. Then, we have

$$\bar{\mu}(\phi, \phi, L) = \frac{\mu(1-p)}{\mu(1-p) + (1-\mu)p} < \frac{1}{2} \quad \text{and}$$
$$\bar{\mu}(L, \phi, H) = \frac{\mu(1-ep)}{\mu(1-ep) + (1-\mu)(1-e(1-p))} < \frac{1}{2}$$

  if μ is close to $\frac{1}{2}$ or e is close to 1 for the second inequality to hold.

This proves the part for the existence of D-equilibrium.

A.1.2 The Existence of S-equilibrium

When BOP is shared between the two litigants, a party wins under an ambiguous report profile while the other party wins under the other ambiguous report profile, in which case there are two possible cases:

- Case 1: D wins under (L, ϕ, H) but P wins under (ϕ, ϕ, L)
- Case 2: P wins under (L, ϕ, H) but D wins under (ϕ, ϕ, L)

We show that an equilibrium exists only in Case 1. To this end, let us first consider Case 1, followed by Case 2.

Case 1:

Suppose J decides that D wins under (L, ϕ, H) but loses under (ϕ, ϕ, L). Then, since P wins under the report profiles (L, ϕ, L), (L, H, L), and (ϕ, ϕ, L), P's payoff (i.e., winning probability), denoted by κ^S, is given by

$$\kappa^S(s_P, s_D) = u_P(L, \phi, L) + u_P(L, H, L) + u_P(\phi, \phi, L)$$

where each term is defined as before. It is straightforward to prove the following lemma:

Lemma 3. *Assume that D wins under (L, ϕ, H) but P wins under (ϕ, ϕ, L). In Pretrial Stage, the following is each player's behavior:*

- *P consults an expert if and only if $c \leq \kappa^S(1, s_D) - \kappa^S(0, s_D)$, and*
- *D consults an expert if and only if $c \leq \kappa^S(s_P, 0) - \kappa^S(s_P, 1)$.*

To find the litigants' equilibrium strategies in Pretrial Stage, we define the following quantities:

$$
\begin{aligned}
&c_0^S \equiv \kappa^S(0,0) - \kappa^S(0,1) = \mu \cdot ep(1-p) + (1-\mu) \cdot ep(1-p) \\
&c_1^S \equiv \kappa^S(1,0) - \kappa^S(0,0) = 0 \\
&c_2^S \equiv \kappa^S(1,0) - \kappa^S(1,1) = \mu \cdot (1-e(1-p))e(1-p)p + (1-\mu) \cdot (1-ep)e(1-p)p \\
&c_3^S \equiv \kappa^S(1,1) - \kappa^S(0,1) = \mu \cdot e(1-p)e(1-p)p + (1-\mu) \cdot epep(1-p)
\end{aligned}
$$

where each c_i^S retains the same meaning as before. These quantities can be ordered as the following lemma shows:

Lemma 4. $c_1^S < c_3^S < c_2^S < c_0^S$.

Proof. We have:

$$
\begin{aligned}
c_0^S - c_3^S &= \mu ep(1-p)(1-e(1-p)) + (1-\mu)ep(1-p)(1-ep) > 0 \\
c_0^S - c_2^S &= e^2p(1-p)(\mu(1-p) + p(1-\mu)) > 0 \\
c_3^S - c_2^S &= ep(1-p)(2e(\mu(1-p) + (1-\mu)p) - 1) < 0
\end{aligned}
$$

Although the first and second inequalities are straightforward to verify, the third one is less so. To see that $c_3^S - c_2^S < 0$, observe

$$
c_3^S - c_2^S < 0 \quad \Longleftrightarrow \quad e(\mu(1-p) + (1-\mu)p) < \frac{1}{2}
$$

Let $f(\mu, p, e) \equiv e(\mu(1-p) + (1-\mu)p)$. Differentiating f with respect to μ, p, and e gives

$$
\begin{aligned}
\frac{\partial f}{\partial \mu} &= e(1-2p) < 0 \\
\frac{\partial f}{\partial p} &= e(1-2\mu) \leq 0 \\
\frac{\partial f}{\partial e} &= \mu(1-p) + (1-\mu)p > 0.
\end{aligned}
$$

Considering the constraints $\mu \geq \frac{1}{2}$, $p > \frac{1}{2}$, and $\mu < p$, f is maximized when $\mu = p = \frac{1}{2}$ and $e = 1$. At this point, f takes the value of $\frac{1}{2}$, which means that for all (μ, p, e) within the given constraint, $f(\mu, p, e) < \frac{1}{2}$ holds, which establishes that $c_3^S - c_2^S < 0$. □

Then, it is straightforward to establish the following lemma that summarizes the litigants' equilibrium strategies:

Lemma 5. *Suppose that BOP is shared (in particular, D wins under (L, ϕ, H) and P wins under (ϕ, ϕ, L)) in equilibrium. Then, the following are the litigants' equilibrium strategies in*

Pretrial Stage:

- *If $\bar{c}_S^N < c$, no litigant consults an expert*
- *If $\underline{c}_S^N < c \leq \bar{c}_S^N$, only D consults an expert*
- *If $c \leq \underline{c}_S^N$, both litigants consult an expert*

where $\bar{c}_S^N \equiv c_0^S$ and $\underline{c}_S^N \equiv c_3^S$.

Finally, let us check if these strategies are consistent with J's belief:

- Suppose $\bar{c}_S^N < c$ so that no one consults. Then, we have

$$\bar{\mu}(\phi, \phi, L) = \frac{\mu(1-p)}{\mu(1-p) + (1-\mu)p} < \frac{1}{2}.$$

- Suppose $\underline{c}_S^N < c \leq \bar{c}_S^N$ so that only D consults an expert. Then, we have

$$\bar{\mu}(\phi, \phi, L) = \frac{\mu(1-ep)(1-p)}{\mu(1-ep)(1-p) + (1-\mu)(1-e(1-p))p} < \frac{1}{2}$$

- Suppose $c \leq \underline{c}_S^N$ so that both consult experts. Then, we have

$$\begin{aligned} \bar{\mu}(L, \phi, H) &= \frac{\mu(1-ep)}{\mu(1-ep) + (1-\mu)(1-e(1-p))} \geq \frac{1}{2} \\ \bar{\mu}(\phi, \phi, L) &= \frac{\mu(1-p)}{\mu(1-p) + (1-\mu)p} < \frac{1}{2} \end{aligned}$$

  where the first inequality holds if e is close to 0 or μ is close to p.

This proves the part for the existence of S-equilibrium (where, in particular, D wins under (L, ϕ, H) and P wins under (ϕ, ϕ, L)).

Case 2:

Consider Case 2 in which P wins under (L, ϕ, H) and D wins under (ϕ, ϕ, L). P's winning probability, denoted by $\kappa^{DP}(s_P, s_D)$, is given by

$$\kappa^{DP}(s_P, s_D) = u_P(L, \phi, L) + u_P(L, \phi, H) + u_P(L, H, L)$$

It is straightforward to show that P consults an expert if and only if $c \leq \kappa^{DP}(1, s_D) - \kappa^{DP}(0, s_D)$ and D consults if and only if $c \leq \kappa^{DP}(s_P, 0) - \kappa^{DP}(s_P, 1)$. We define the following quantities as before:

$$\begin{aligned}
c_0^{DP} &\equiv \kappa^{DP}(0,0) - \kappa^{PD}(0,1) = 0 \\
c_1^{DP} &\equiv \kappa^{DP}(1,0) - \kappa^{PD}(0,0) = \mu \cdot e(1-p) + (1-\mu)ep \\
c_2^{DP} &\equiv \kappa^{DP}(1,0) - \kappa^{PD}(1,1) = \mu \cdot e(1-p)epp + (1-\mu) \cdot epe(1-p)(1-p) \\
c_3^{DP} &\equiv \kappa^{DP}(1,1) - \kappa^{PD}(0,1) = \mu \cdot e(1-p)\{1-ep^2\} + (1-\mu) \cdot ep\{1-e(1-p)^2\}
\end{aligned}$$

where each c_i^{DP} retains the same meaning as before. The following lemma compares the magnitudes of these quantities:

Lemma 6. $c_0^{DP} < c_2^{DP} < c_3^{DP} < c_1^{DP}$.

Proof. That $c_2^{DP} < c_1^{DP}$ and $c_3^{DP} < c_1^{DP}$ is trivial. Letting $g(\mu, p, e) \equiv c_3^{DP} - c_2^{DP}$, we have

$$\frac{\partial g}{\partial \mu} = -e(2p-1)(1+2e(1-p)p) < 0$$

Let $\mu \to p$ to minimize g subject to $\mu < p$. This is

$$g|_{\mu \to p} = 2e(1-p)p(1-e+2ep(1-p)) > 0.$$

Therefore, $g > 0$ for all μ, p, and e, which implies $c_3^{DP} > c_2^{DP}$. □

Given the above result, it is easy to see that the litigants' equilibrium strategies are given by:

- If $c_1^{DP} < c$, no one consults
- If $c_2^{DP} < c \leq c_1^{DP}$, only P consults
- If $c \leq c_2^{DP}$, both litigants consult.

However, we can verify that these equilibrium strategies are inconsistent with the BOP assignment in equilibrium:

- Suppose no one consults. Then, we have

$$\bar{\mu}(\phi, \phi, L) = \frac{\mu(1-p)}{\mu(1-p) + (1-\mu)p} < \frac{1}{2}$$

- Suppose only P consults. Then, we have

$$\bar{\mu}(L, \phi, H) = \mu \geq \frac{1}{2}$$

- Suppose both litigants consult. Then, we have

$$\bar{\mu}(\phi, \phi, L) = \frac{\mu(1-p)}{\mu(1-p) + (1-\mu)p} < \frac{1}{2}$$

All of the inequalities above are inconsistent with the BOP assignment that P wins under (L, ϕ, H) and D wins under (ϕ, ϕ, L). Therefore an equilibrium does not exist in Case 2.

A.2 Proof of Proposition 2

Let us prove that the no-expert thresholds in Game-N are smaller than the no-expert thresholds in Game-B. The respective cost thresholds are given by

$$\begin{aligned}
\bar{c}_P^N &= \mu e(1-p)^2 + (1-\mu)ep^2 \\
\bar{c}_D^N &= \mu ep(1-p) + (1-\mu)ep(1-p) \\
\bar{c}_S^N &= \mu ep(1-p) + (1-\mu)ep(1-p) \\
\bar{c}_P^B &= \mu e(1-p) + (1-\mu)ep \\
\bar{c}_D^B &= \mu ep + (1-\mu)e(1-p)
\end{aligned}$$

It is straightforward to show that

$$\begin{aligned}
\bar{c}_P^B - \bar{c}_D^B &= -e(2\mu-1)(2p-1) \leq 0 \\
\bar{c}_D^N - \bar{c}_P^N &= -e(p-\mu)(2p-1) < 0 \\
\bar{c}_P^N - \bar{c}_P^B &= -ep(1-p) < 0
\end{aligned}$$

from which we can infer that $\bar{c}_S^N = \bar{c}_D^N < \bar{c}_P^N < \bar{c}_P^B \leq \bar{c}_D^B$. In conclusion, $\max\{\bar{c}_P^N, \bar{c}_D^N, \bar{c}_S^N\} < \min\{\bar{c}_D^B, \bar{c}_P^B\}$, which completes the proof.

A.3 Proof of Proposition 3

In order to prove this proposition, we take the following steps. First, we order the thresholds from the equilibria of Game-B and Game-N in order to find out the possible pairs of equilibria from the two games.[17] Second, we compare the decision errors when the equilibrium number of experts hired by the litigants in each game is the same. Finally, we compare the decision errors for the remaining cases.

[17] For example, if $\underline{c}_D^N \leq \underline{c}_P^B$, P-equilibrium with two private experts exists in Game-B and D-equilibrium with one private expert exists in Game-N for $c \in (\underline{c}_D^N, \underline{c}_P^B)$; thus, we need to compare the decision errors between these two equilibria. Observe that this pair of equilibria is not possible if $\underline{c}_P^B < \underline{c}_D^N$, in which case we do not need to compare their decision errors.

Lemma 7. *It is sufficient to prove Proposition 3 under the following ordering of the thresholds:*

$$\underline{c}_S^N < \underline{c}_D^N < \underline{c}_P^B < \bar{c}_D^N = \bar{c}_S^N < \bar{c}_P^N < \bar{c}_P^B \leq \bar{c}_D^B.$$

Proof. That $\bar{c}_D^N = \bar{c}_S^N < \bar{c}_P^N < \bar{c}_P^B \leq \bar{c}_D^B$ is proved in the proof of Proposition 2. We can show that

$$\begin{aligned}
\underline{c}_D^N - \underline{c}_S^N &= \mu ep(1-p)(1-e+e(1-p)) + (1-\mu)ep(1-p)(1-e+ep) > 0 \\
\underline{c}_P^B - \underline{c}_S^N &= epe(1-p)(\mu p + (1-\mu)(1-p)) > 0 \\
\bar{c}_D^N - \underline{c}_P^B &= e(1-e)p(1-p) > 0 \\
\bar{c}_D^N - \underline{c}_D^N &= epe(1-p)(2p-1)(2\mu-1) \geq 0
\end{aligned}$$

which suggest that there are two possible cases:

- $\underline{c}_S^N < \underline{c}_D^N < \underline{c}_P^B < \bar{c}_D^N = \bar{c}_S^N < \bar{c}_P^N < \bar{c}_P^B \leq \bar{c}_D^B$
- $\underline{c}_S^N < \underline{c}_P^B \leq \underline{c}_D^N \leq \bar{c}_D^N = \bar{c}_S^N < \bar{c}_P^N < \bar{c}_P^B \leq \bar{c}_D^B$

Observe that the only difference between the two cases above is that $\underline{c}_P^B$ is smaller than $\underline{c}_D^N$ in the second case. Considering the second case, for $c \in (\underline{c}_P^B, \underline{c}_D^N)$, P-equilibrium with one private expert exists in Game-B while D-equilibrium with two private experts may exist in Game-N. However, if we compare these two equilibria, the decision errors from D-equilibrium of Game-N is clearly smaller due to the additional court-appointed expert. Because the remaining pairs of possible equilibria from the two games are the same under the two cases above, we can focus on the first case. □

Let us define $E_k^{i(j)}$ as the measure of decision errors where k private experts are hired in Game-i's j-Equilibrium. Then, the decision errors in each equilibrium can be calculated as follows:

- Game-B:

$$\begin{aligned}
E_0^{B(P)} &= 1-\mu \\
E_1^{B(P)} &= \mu e(1-p) + (1-\mu)(1-ep) \\
E_2^{B(P)} &= \mu e(1-p)(1-ep) + (1-\mu)(1-ep(1-e+ep))
\end{aligned}$$

$$E_1^{B(D)} = \mu(1-ep) + (1-\mu)e(1-p)$$

- Game-N:

$$E_1^{N(P)} = \mu e(1-p)(1-p) + (1-\mu)(1-ep^2)$$

$$\begin{aligned}
E_0^{N(D)} &= (1-p) \\
E_1^{N(D)} &= \mu(1-ep)(1-p) + (1-\mu)(1+ep)(1-p) \\
E_2^{N(D)} &= (1-p)\{epe(1-p) + (1-ep)(1+ep)\}
\end{aligned}$$

$$\begin{aligned}
E_0^{N(S)} &= (1-p) \\
E_1^{N(S)} &= \mu(1-ep)(1-p) + (1-\mu)(1+ep)(1-p) \\
E_2^{N(S)} &= \mu\{1-ep(1-e(1-p))\}(1-p) + (1-\mu)\{1+ep(1-ep)\}(1-p)
\end{aligned}$$

With these terminologies, let us compare the decision errors between the two games when the equilibrium number of private experts is the same: that is, when (i) no private expert is hired, (ii) one private expert is hired, and (iii) two private experts are hired in both games.

(i) Since $\mu < p$, we have $E_0^{B(P)} > E_0^{N(D)} = E_0^{N(S)}$. Thus, the decision errors are smaller in Game-N.

(ii) For Game-N, $E_1^{N(D)} = E_1^{N(S)}$ and $E_1^{N(P)} - E_1^{N(D)} = (1-e)(p-\mu) > 0$. For Game-B, $E_1^{B(D)} - E_1^{B(P)} = (1-e)(2\mu-1) \geq 0$. But $E_1^{B(P)} - E_1^{N(P)} = ep(2\mu-1)(1-p) \geq 0$, that is, the smallest error in Game-B is greater than or equal to the largest error in Game-N. Thus, the decision errors are smaller in Game-N.

(iii) We have $E_2^{B(P)} > E_2^{N(D)}$ because

$$E_2^{B(P)} - E_2^{N(D)} = (p-\mu)((1-e) + 2epe(1-p)) > 0$$

To show $E_2^{B(P)} \geq E_2^{N(S)}$ observe that the following inequality holds:

$$\begin{aligned}
E_2^{B(P)} - E_1^{N(S)} &= -\mu(1-e)(1-p)(1-ep) + (1-\mu)(1-e)p(1-e(1-p)) \\
&= (1-e)\{(1-\mu)p(1-e(1-p)) - \mu(1-p)(1-ep)\} \\
&\geq (1-e)\{(1-p)p(1-e(1-p)) - p(1-p)(1-ep)\} \quad (\because \mu < p) \\
&> 0.
\end{aligned}$$

Because the decision errors decrease as the number of experts increases, we have $E_1^{N(S)} \geq E_2^{N(S)}$. Thus, combining these two inequalities, we have $E_2^{B(P)} \geq E_2^{N(S)}$. Thus, the decision errors are smaller in Game-N.

Therefore, if the equilibrium number of experts hired by the litigants is the same across the two games, the decision errors are smaller in Game-N.

Now we are left to consider two remaining cases: (i) one private expert in Game-B but no private expert in Game-N, and (ii) two private experts in Game-B but only one private expert in Game-N. First, consider case (i). We have $E_1^{B(P)} \leq E_1^{B(D)}$ and

$$E_0^{N(D)} - E_1^{B(P)} = E_0^{N(S)} - E_1^{B(P)} = -(1-e)(p-\mu) < 0$$

which implies that the decision errors are smaller in Game-N. Second, consider case (ii). We have

$$E_1^{N(P)} - E_2^{B(P)} = -e(1-e)p(1-p)(2\mu - 1) \leq 0$$

and $E_1^{N(D)} = E_1^{N(S)} \leq E_2^{B(P)}$ which proves that the decision errors are smaller in Game-N.

In sum, we conclude that the the decision errors in Game-B are at least as large as those in Game-N.

A.4 Proof of Proposition 4

Take P-Equilibrium from Game-B and D-equilibrium from Game-N. From Lemma 7, the cost thresholds ordering was given by

$$\underline{c}_D^N \sim \underline{c}_P^B \leq \bar{c}_D^N < \bar{c}_P^B$$

where $\sim$ denotes ambiguous ordering.

The decision errors were given by

$$\begin{aligned}
E_0^{B(P)} &= 1 - \mu \\
E_1^{B(P)} &= \mu e(1-p) + (1-\mu)(1-ep) \\
E_2^{B(P)} &= \mu e(1-p)(1-ep) + (1-\mu)(1-ep(1-e+ep)) \\
E_0^{N(D)} &= 1 - p \\
E_1^{N(D)} &= \mu(1-ep)(1-p) + (1-\mu)(1+ep)(1-p) \\
E_2^{N(D)} &= (1-p)\{epe(1-p) + (1-ep)(1+ep)\}
\end{aligned}$$

Accordingly, the social cost in each equilibrium can be calculated as

$$\begin{aligned}
SC_2^{B(P)} &= E_2^{B(P)} + C_2^{B(P)} \\
&= \mu e(1-p)(1-ep) + (1-\mu)(1-ep(1-e+ep)) + 2c \\
SC_1^{B(P)} &= E_1^{B(P)} + C_1^{B(P)}
\end{aligned}$$

$$
\begin{aligned}
&= \mu e(1-p) + (1-\mu)(1-ep) + c \\
SC_0^{B(P)} &= E_0^{B(P)} + C_0^{B(P)} \\
&= 1-\mu \\
SC_2^{N(D)} &= E_2^{N(D)} + C_2^{N(D)} \\
&= (1-p)\left(epe(1-p) + (1-ep)(1+ep)\right) + 2c + c_J \\
SC_1^{N(D)} &= E_1^{N(D)} + C_1^{N(D)} \\
&= \mu(1-ep)(1-p) + (1-\mu)(1+ep)(1-p) + c + c_J \\
SC_0^{N(D)} &= E_0^{N(D)} + C_0^{N(D)} \\
&= 1-p+c_J
\end{aligned}
$$

For completeness, we consider two cases.

- Case 1: $\underline{c}_D^N \leq \underline{c}_P^B \leq \bar{c}_D^N < \bar{c}_P^B$.

  Suppose the cutoffs are ordered as above. If $c \in (0, \underline{c}_D^N]$, we have

  $$
  \begin{aligned}
  SC^B &= SC_2^{B(P)} \\
  SC^N &= SC_2^{N(D)}
  \end{aligned}
  $$

  The social planner allows court-appointed experts if

  $$(1-p)\left(epe(1-p) + (1-ep)(1+ep)\right) + 2c + c_J \leq \mu e(1-p)(1-ep) + (1-\mu)(1-ep(1-e+ep)) + 2c$$

  or

  $$c_J \leq (p-\mu)(1-e+2e^2p(1-p))$$

  If $c \in (\underline{c}_D^N, \underline{c}_P^B]$, we have

  $$
  \begin{aligned}
  SC^B &= SC_2^{B(P)} \\
  SC^N &= SC_1^{N(D)}
  \end{aligned}
  $$

  The social planner allows court-appointed experts if

  $$\mu(1-ep)(1-p) + (1-\mu)(1+ep)(1-p) + c + c_J \leq \mu e(1-p)(1-ep) + (1-\mu)(1-ep(1-e+ep)) + 2c$$

  or

  $$c_J \leq (1-e)(p(1+e(1-p)(2\mu-1)) - \mu) + c$$

If $c \in (\underline{c}_P^B, \bar{c}_D^N]$, we have

$$SC^B = SC_1^{B(P)}$$
$$SC^N = SC_1^{N(D)}$$

The social planner allows court-appointed experts if

$$\mu(1-ep)(1-p) + (1-\mu)(1+ep)(1-p) + c + c_J \leq \mu e(1-p) + (1-\mu)(1-ep) + c$$

or

$$c_J \leq \mu(1-p)(e-1+ep) + (1-\mu)(1-ep-(1+ep)(1-p))$$

If $c \in (\bar{c}_D^N, \bar{c}_P^B]$, we have

$$SC^B = SC_1^{B(P)}$$
$$SC^N = SC_0^{N(D)}$$

The social planner allows court-appointed experts if

$$1 - p + c_J \leq \mu e(1-p) + (1-\mu)(1-ep) + c$$

or

$$c_J \leq (1-e)(p-\mu) + c$$

Finally, if $c \in (\bar{c}_P^B, \infty)$, we have

$$SC^B = SC_0^{B(P)}$$
$$SC^N = SC_0^{N(D)}$$

The social planner allows court-appointed experts if

$$1 - p + c_J \leq 1 - \mu$$

or

$$c_J \leq p - \mu$$

- Case 2: $\underline{c}_P^B < \underline{c}_D^N \leq \bar{c}_D^N < \bar{c}_P^B$.

  Under the second case, the only difference from the above case is that it allows the existence of a cost range at which no expert is hired in Game-N whereas one expert is hired in Game-B. Hence it is enough to additionally consider the case for $c \in (\underline{c}_P^B, \underline{c}_D^N]$.

In this case, we have

$$SC^B = SC_1^{B(P)}$$
$$SC^N = SC_0^{N(D)}$$

The social planner allows court-appointed experts if

$$1 - p + c_J \leq \mu e(1-p) + (1-\mu)(1-ep) + c$$

or

$$c_J \leq (1-e)(p-\mu) + c$$

which completes the proof.

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