Centralized vs. Decentralized Institutions for Expert Testimony

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Abstract

The legal community has been debating the question of who should select and provide expert witnesses at trial: the litigant or the judge? Using a persuasion-game framework, I show that there is a trade-off. On the one hand, the litigant is willing to consult an expert even when the judge is reluctant to appoint her own experts due to high costs. On the other hand, given the same amount of expert advice, the judge can make a more accurate decision when using a court-appointed expert's advice at trial. I show that the cost of expert advice is an important factor in this trade-off and, therefore, in the argument for the reform toward a centralized system for expert witnesses.

Keywords: expert witnesses, decentralized institution, centralized institution, persuasion game, evidence distortion.
JEL: C72, K41.

1 Introduction

In the current American legal system, expert witnesses are selected and retained by litigants, which I call the *decentralized institution*. Thus, self-interested litigants invest in strong statements for their causes by searching for and retaining favorable expert witnesses. Proponents of such an institution argue that the competitive nature of the system provides litigants with

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strong incentives to collect and reveal evidence to defend their causes, in which process the truth is found.[1]

Opponents of the present system, however, argue that the "battles of the experts" observed in many civil litigations are obstacles to finding the truth. As expert witnesses are selected by and affiliated with the litigants, there exists inevitable evidence distortion: only those experts whose opinions align with the litigants' interests will be heard at trial. Such opportunistic behavior by the litigants with the help of their hired guns may work to the detriment of the accuracy of the final verdict, and thereby place the legitimacy of the legal procedure itself in question. Concerned about the drawbacks, many scholars have long argued for a more centralized system for expert witnesses, which I call the *centralized institution*, thereby allowing judges to appoint neutral experts.[2] In particular, there have been numerous reform proposals suggesting that the court appoint its own experts, thereby enhancing the inquisitorial component in the American legal system.[3] The main task of this paper is to evaluate such reform proposals, focusing especially on the accuracy of the legal system.[4]

The main results show that there is a trade-off between the two institutional arrangements. On the one hand, the litigants are willing to consult an expert even when the court is reluctant to appoint its own experts due to high costs. More precisely, there exists an interval of cost parameters such that no expert is utilized in the centralized institution, whereas an expert is utilized in the decentralized institution when the cost of using expert advice lies in the interval. This result obtains because the court, as an impartial decision-maker, must weigh the possibility that "bad news" lead to an incorrect decision because expert advice provides imperfect information about the truth. Proposition 3 shows the ways in which such consideration by the court reduces its incentive to utilize expert advice relative to the litigants' incentives. On the other hand, given the same amount of expert advice in both institutions, the trier of fact can make a more accurate decision when using a court-appointed expert's advice at trial. As litigants attempt to distort evidence, there exists an information loss

[1] Posner (1988, 1999) present strong arguments for such decentralized institutions.

[2] Federal Rule of Evidence 706 states that the court may appoint expert witnesses of its own selection. However, Rule 706 has been infrequently invoked since its enactment because, among other reasons, many judges have been reluctant to appoint experts out of a concern that doing so will interfere with the adversarial process (Cecil and Willging, 1994).

[3] 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 in order 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), argued that the appropriate remedy to adversarial bias (combined with inexpert juries) was increased reliance on court-appointed, nonpartisan experts.

[4] Although the main body of this paper is presented in a civil-litigation context, the result is not limited to it. See Section 6.4 for an interpretation of the model in a criminal-litigation context.

under the decentralized institution. This behavior by litigants increases uncertainty faced by the trier of fact, leading to a less-accurate decision than in the centralized institution. Propositions 4 and 5 provide more precise statements.

The main model in this paper is a persuasion game with endogenous information acquisition, which is adapted from Kim (2014a). In that paper, I study two commonly used forms of legal processes, the adversarial and inquisitorial systems,[5] within a persuasion-game environment, and show the conditions in which one system dominates the other in terms of accuracy. An important assumption is that both litigants have access to the same source of information, and therefore they obtain the same piece of evidence if they were successful in collecting information before a trial occurs. This assumption is crucial to the finding that only one litigant searches for information in equilibrium. In contrast, the current paper assumes that litigants have access to different information sources because each litigant seeks advice from an expert who may possess pieces of evidence different from others. The main results demonstrate that both litigants may consult an expert in equilibrium, depending on the cost of expert advice. Thus, the competition between the litigants in the pursuit of more favorable evidence for their own causes is better modeled in the current paper.

In general, economic analysis has been in favor of 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 possessed by litigants is eventually revealed to the fact finder because of competition among them: as a piece of evidence detrimental to one party is beneficial to the other, any evidence is eventually revealed by one of the competing parties. This intuition has been confirmed to be robust (albeit not free from debate) in a more general environment, and has provided strong support for the current form of the American legal system.[6] Although the extant literature focuses on communication problems between informed players and an uninformed decision-maker, the current paper adds one more dimension to the literature by introducing players' information acquisition behavior.

[5]For an important debate on the relative merits of the adversarial and inquisitorial systems, see Posner (1988, 1999) and Tullock (1975, 1980, 1988). The distinction between the decentralized institution and the adversarial system (the centralized institution and the inquisitorial system) is subtle. The adversarial system is a legal system in which the case under dispute is organized and developed by the initiatives of the interested parties, rather than by an impartial third party. In theory, the adversarial system can coexist with the centralized institution, relegating to the court only the role of providing the judge with expert witnesses, which is the current development of the debate regarding the reform of expert law in the United States. The focus of the current paper is only on the rule governing expert witnesses, rather than on a broader discussion on the relative merits of the adversarial system over the inquisitorial system.

[6]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) for the same line of research. Also see Froeb and Kobayashi (2001), Parisi (2002), and Emons and Fluet (2009a,b) for related research.

Using a principal-agent model, Dewatripont and Tirole (1999), Palumbo (2001, 2006), Iossa and Palumbo (2007), Deffains and Demougin (2008), and Kim (2014b) study whether information can be provided to the fact finder at a lower cost in decentralized systems. These models also provide strong support for decentralized systems, showing that incentive constraints are easily satisfied by exploiting competition among agents. Thus, pointing out another merit of employing decentralized systems, this line of research complements the persuasion-game approach adopted in the current paper.

The remainder of the current paper is organized as follows. Section 2 presents the basic model used for subsequent analysis. Section 3 analyzes the decentralized institution, Section 4 investigates the centralized institution, and Section 5 compares the two institutions in terms of accuracy. Finally, Section 6 concludes with a discussion. Proofs of the propositions appear in the Appendix.

2 Model

Consider a lawsuit in which a plaintiff (henceforth P) contends with a defendant (henceforth D). Each litigant pleads for his cause, and a judge (henceforth J) must decide whose cause should prevail at trial. J wants to make a correct decision accurately reflecting the true state $t \in \{h, l\}$. When $t = h$, J obtains a payoff of 1 if she rules in favor of D, and a payoff of 0 otherwise. Similarly, when $t = l$, J obtains a payoff of 1 if she rules in favor of P, and a payoff of 0 otherwise. In contrast, each litigant wants to win at trial regardless of $t \in \{h, l\}$: a litigant obtains a payoff of 1 if he wins at trial, and a payoff of 0 otherwise. The prior probability that $t = h$ is denoted by $\mu = P(t = h)$.

To assist J with finding the truth, experts may be called to testify at trial.[7] An expert is someone better equipped than laypersons through "knowledge, skill, experience, training, or education (Federal Rule of Evidence 702)" to perceive the truth in his specialized domains. He can tell whether the plaintiff's illness is due to exposure to specific toxic chemicals from the workplace, whether the plaintiff underwent erroneous medical treatment in the hospital, and so forth. Such testimony provided by expert witnesses is valuable, sometimes crucial, in the fact-finding process, particularly when the dispute involves scientific and technical issues. As such, experts play an important role in civil litigation. Formally, each expert has access to a conditionally *i.i.d.* random variable x with probability[8] $e \in (0, 1)$, where x takes the value of either H or L with the conditional probability $P(H|h) = P(L|l) = p > \frac{1}{2}$.

[7] Gross (1991) notes that experts testified in 86% of civil trials in a sample of California cases between 1985 and 1986.

[8] Thus, an expert observes the realization of x with probability e and cannot observe it with probability $1 - e$.

Note that $x = H$ can be said to be "favorable" evidence for D and "unfavorable" evidence for P because, as clarified in the main analysis, if J observes $x = H$, she believes that $t = h$ is more likely to be the true state and thereby rules in favor of D. Similarly, $x = L$ can be said to be favorable evidence for P and unfavorable evidence for D. Also note that e can be thought of as the expert's quality. If e is close to 1, the expert can be relied upon to provide valuable evidence for the issue, whereas if e is close to 0, the expert's ability is questionable and is unlikely to be able to provide the trier of fact with useful guidance. I assume that all available experts have the same quality, i.e., they have the same chance of receiving information upon investigation.[9] Another measure of an expert's quality in the model is p because as p increases, the evidence collected by an expert becomes more accurate. Note that an expert's quality in this sense cannot be lower than the prior probability μ because if p is smaller than μ, the evidence x is not precise enough to persuade J to change her decision depending on the realization of x. Thus, I assume $\mu \in (1 - p, p)$, which guarantees that J's decision is responsive to the evidence and helps us avoid uninteresting cases.

In the current American legal system, expert witnesses are selected and retained by litigants, which I call the decentralized institution (henceforth DI). Opponents of the present system argue for a more centralized system for expertise, which I call the centralized institution (henceforth CI), thereby allowing judges to appoint neutral experts. The main task of this paper is to study the strength and weakness of each institution, focusing especially on accuracy.

Formally, DI is modeled as an incomplete information dynamic game with two stages, Pretrial Stage and Trial Stage. In Pretrial Stage, by paying a cost $c > 0$,[10] a litigant $i \in \{P, D\}$ can secretly[11] consult (at most) one expert to obtain evidence to present at trial. If his expert observes the hidden evidence, the litigant obtains $x_i \in \{H, L\}$. A litigant cannot obtain any evidence if either he does not consult an expert or his expert cannot observe the hidden evidence.

In Trial Stage, litigants present their evidence to J, and I denote a litigant i's presentation by r_i. I assume that the evidence is verifiable, so litigants can choose to hide but cannot falsify the evidence presented to J. Thus, when a litigant obtained x_i from his expert, he either truthfully reveals it, $r_i = x_i$, or hides it as an attorney's work product[12] and remains

[9] 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 sprit to the proposal by Robertson (2010). The result is the same under both approaches.

[10] This cost may include the cost of searching for experts, preparing a dossier for them, reviewing their technical reports, separating relevant pieces of evidence from irrelevant ones, and so forth.

[11] That is, a litigant's action is not observable to J and the other litigant.

[12] Robertson (2010) notes at p.210: "Under the attorney work product doctrine, if a litigant consults with an expert but does not designate her as a trial witness, then the expert's opinions are generally not discoverable by the adversary. (According to Federal Rule of Civil Procedure 26(b)(4): [A] party may not ...

silent, $r_i = \phi$. If a litigant has no evidence, he remains silent, $r_i = \phi$. Thus, when a litigant remains silent, J cannot ascertain whether the litigant is hiding evidence or simply uninformed. In such a situation, J forms a Bayesian posterior incorporating her belief about the litigants' strategies. Finally, J makes a decision regarding which party wins at trial, payoffs are realized, and the game ends.

In contrast, CI is modeled as a decision-making problem in which J makes a decision directly consulting experts for evidence and paying a cost $c > 0$. To make the two institutions, CI and DI, comparable, I assume that J can consult at most two experts in CI so that the maximum number of experts consulted in each institution is 2. I also assume that the cost of consulting an expert is the same in both institutions.

In the following analysis, I first analyze DI and find the perfect Bayesian equilibrium that is simply referred to as the equilibrium. I then proceed to the analysis of CI and compare the results from the two institutions.

3 Decentralized Institution

3.1 Trial Stage

I first analyze the players' behavior in Trial Stage. It is straightforward to see that the litigants only reveal favorable evidence (i.e., P never reveals $x_P = H$ whereas D never reveals $x_D = L$) because revealing unfavorable evidence only reduces their chances of winning. Thus, evidence distortion naturally arises in Trial Stage, and J must account for such incentives of the litigants when observing the litigants' presentations.[13]

In the presence of evidence distortion by the litigants, there are four possible situations:

1. $(r_P, r_D) = (L, \phi)$: P wins

2. $(r_P, r_D) = (\phi, H)$: D wins

3. $(r_P, r_D) = (L, H)$: J's decision depends on μ

discover facts known or opinions held by an expert who has been retained or specially employed by another party in anticipation of litigation or to prepare for trial and who is not expected to be called as a witness at trial. But a party may do so ... on showing exceptional circumstances under which it is impracticable for the party to obtain facts or opinions on the same subject by other means.)" Gross (1991) also notes at p.1143: "A party that takes full advantage of these [discovery] rules can "informally consult" with a dozen experts (a non-discoverable activity), retain the five experts who seem most promising (a generally non-discoverable activity), and, finally, at the last available date, designate the one of these five whose opinion is most favorable as an expert witness."

[13] This feature is not new to the literature, and many papers examine various models in which evidence distortion is introduced in one way or another. See Sobel (2013) for a survey on this topic.

4. $(r_P, r_D) = (\phi, \phi)$: J's decision depends on her belief about the litigants' behavior.

To be more precise, consider the first situation, in which J observes L from P and D remains silent. The "low" signal from P alone reduces J's posterior belief below $\frac{1}{2}$.[14] As D's silence cannot increase J's posterior belief,[15] it is easy to establish that J rules in favor of P. The reasoning under the second situation is analogous. In the third situation, both litigants reveal evidence supporting their own claims. As the signals are conditionally *i.i.d.*, these two pieces of evidence nullify each other, inducing J to hold a posterior belief equal to the prior belief. Thus, D wins if $\mu \geq \frac{1}{2}$, and P wins otherwise. This situation shows why DI is vulnerable to criticisms such as "war of attrition" or "money contest."[16] By consulting experts and selectively presenting evidence that is favorable to their causes, the litigants can provide the trier of fact with the impression that the issue at hand is subject to contestation, which leaves her equipoised without any change in her assessment regarding the dispute.

In the fourth situation, J receives no "direct" evidence because both litigants remain silent. However, she could obtain "indirect" evidence from the litigants' behavior:

(a) First, suppose that J believes that no litigant consulted an expert in Pretrial Stage. Then, J believes that both litigants are silent because they are simply uninformed, and therefore J's posterior belief is equal to the prior belief. Thus, D wins if $\mu \geq \frac{1}{2}$, and P wins otherwise.

(b) Second, suppose J believes that only one litigant consulted an expert in Pretrial Stage. It turns out that J forms a posterior belief "against" that litigant. For example, if J believes that only P consulted an expert, her posterior belief in the no-evidence event $(r_P, r_D) = (\phi, \phi)$, denoted as $\mu(\phi, \phi)$, is given by

$$\begin{aligned} \mu(\phi, \phi) &= \frac{\mu q_h}{\mu q_h + (1-\mu) q_l} \\ &= \frac{\mu(ep + 1 - e)}{\mu(ep + 1 - e) + (1-\mu)(e(1-p) + 1 - e)} \end{aligned} \tag{1}$$

[14] To be more precise, if J observes $x = L$ her posterior belief becomes (disregarding D's presentation)

$$P(t = h | x = L) = \frac{\mu(1-p)}{\mu(1-p) + (1-\mu)p} < \frac{1}{2}$$

where the inequality holds because $\mu \in (1-p, p)$.

[15] D is silent when he is uninformed or hiding $x_D = L$. In the former case, there should be no change in J's posterior belief. In the latter case, J's posterior belief must fall. As J's posterior belief is a convex combination of those two beliefs, the posterior cannot increase following D's silence.

[16] In his papers, Tullock criticizes such decentralized legal systems for leading to excessive expenditures through unnecessary duplication and costly overproduction of misleading information. See Tullock (1975, 1980, 1988).

$$> \quad \mu$$

where q_t is the probability that P remains silent given $t \in \{h, l\}$; e.g., given that the true state is high, P remains silent either because he obtained unfavorable evidence ($x_P = H$) from his expert (with probability ep) or his expert could not observe the hidden evidence (with probability $1 - e$), which gives us q_h. If P's silence is due to his manipulation, J's posterior belief must be higher than μ, and if P's silence is due to no information, J's posterior belief must be equal to μ. Thus, J's posterior belief, which is a convex combination of the beliefs under the two possibilities, becomes "higher" (i.e., "against" P) if she believes that only P consulted an expert. Based on J's posterior belief, D wins if $\mu(\phi, \phi) \geq \frac{1}{2}$, and P wins otherwise.

(c) Third, if J believes that both litigants consulted an expert, her posterior belief is equal to the prior belief because the indirect evidence from each litigant's silence nullifies one another.[17] Thus, D wins if $\mu \geq \frac{1}{2}$, and P wins otherwise.

At this point, J's belief about which litigant has consulted an expert can be arbitrary. In equilibrium, however, her belief must be consistent with the litigants' strategies, which will be clarified in Section 3.3. When no direct evidence is revealed in Trial Stage, D wins if $\mu(\phi, \phi) \geq \frac{1}{2}$, and P wins otherwise. I say the burden of proof (henceforth BOP[18]) is on P if $\mu(\phi, \phi) \geq \frac{1}{2}$ and on D otherwise.

Definition 1. *BOP is said to be on P if $\mu(\phi, \phi) \geq \frac{1}{2}$ and on D otherwise.*

Note that if a litigant bears BOP, he knows that he can win only when he presents favorable evidence in Trial Stage. For example, suppose P bears BOP. If P cannot reveal $x_P = L$ (which implies that P will remain silent), J will eventually observe $(r_P, r_D) = (\phi, H)$ or $(r_P, r_D) = (\phi, \phi)$ in Trial Stage, and both cases lead to D's winning.

3.2 Pretrial Stage

Using backward induction, I now analyze the litigants' behavior regarding their decisions to consult an expert in Pretrial Stage. Throughout the analysis, I assume that BOP falls on P.

[17] This is because I assume that the experts have the same chance of observing the evidence. If I assume that the litigants randomly contact an expert from a pool of heterogeneous experts, I obtain the same result. See Sharif and Swank (2012) for an analysis of heterogeneity among litigants.

[18] BOP is "one of the slipperiest members of the family of legal terms" (the U.S. Supreme Court, 2011), and it refers to many doctrinal concepts that overlap but are not fully interchangeable. See Talley (2013) for a survey of this important topic. In this paper, BOP can be interpreted as the *burden of production* in the sense that failure to produce required evidence (e.g., $x_P = L$ for P) means losing the case.

The opposite case in which BOP falls on D easily follows because the result is symmetric, and therefore its analysis is omitted to save space. The analysis of this section is separated into two parts, depending on the prior probability: $\mu \geq \frac{1}{2}$ and $\mu < \frac{1}{2}$.

3.2.1 Prior in favor of D

In this subsection, I assume $\mu \geq \frac{1}{2}$. P's expected payoff is (remember that BOP is on P)

- 0 if he does not consult an expert, or
- $\underbrace{\mu e(1-p)(1-ep\cdot s_D)+(1-\mu)ep(1-e(1-p)\cdot s_D)}_{(*)\text{ prob. of P's winning}} - c$ if he consults an expert

where $s_D = 1$ if D contacts an expert and $s_D = 0$ otherwise.

If P does not consult an expert (leading to $r_P = \phi$), it is obvious that he will lose in Trial Stage because D's presentation is either $r_D = H$ (leading to $(r_P, r_D) = (\phi, H)$) or $r_D = \phi$ (leading to $(r_P, r_D) = (\phi, \phi)$) and P loses in both cases. Thus, P's expected payoff is 0.

If P consults an expert, it is straightforward to check that P wins in Trial Stage only under $(r_P, r_D) = (L, \phi)$. In this case, the probability of P's winning $(*)$ depends on P's belief about D's action:

(a) If D does not contact an expert ($s_D = 0$), the probability of P's winning $(*)$ is given by

$$\mu e(1-p)+(1-\mu)ep \quad = \quad e\underbrace{(\mu(1-p)+(1-\mu)p)}_{=P(x_P=L)}$$

where $P(x_P = L)$ is the unconditional probability that the hidden information is L. Because D does not provide any evidence, there are only two possibilities in Trial Stage: $(r_P, r_D) = (L, \phi)$ or $(r_P, r_D) = (\phi, \phi)$. That is, P wins if and only if he can obtain and reveal $x_P = L$ to J, whose probability is given above. This probability gives us P's expected payoff as proposed if $s_D = 0$.

(b) If D contacts an expert ($s_D = 1$), the probability of P's winning $(*)$ is given by

$$\mu \underbrace{e(1-p)}_{(A1)}\underbrace{(1-ep)}_{(A2)} + (1-\mu)ep(1-e(1-p)).$$

Note that P cannot secure his winning by revealing $x_P = L$ in Trial Stage because D can "counteract" P's evidence by revealing $x_D = H$, in which case J's posterior belief is equal to $\mu \geq \frac{1}{2}$ and therefore D wins. Thus, if $s_D = 1$, the probability of P's winning $(*)$ is lower than under $s_D = 0$: $(A1)$ is the probability that P obtains $x_P = L$ given

D $\diagdown$ P	Consult	Not
Consult	$1-\{\mu e(1-p)(1-ep)+(1-\mu)ep(1-e(1-p))\}-c$	$1-c$
	$\mu e(1-p)(1-ep)+(1-\mu)ep(1-e(1-p))-c$	0
Not	$1-\{\mu e(1-p)+(1-\mu)ep\}$	1
	$\mu e(1-p)+(1-\mu)ep-c$	0

Table 1: Payoff Table in Pretrial Stage (BOP on P and $\mu \geq \frac{1}{2}$)

$t = h$, and $(A2)$ is the probability that D remains silent given $t = h$. Thus, $(A1) \times (A2)$ is the probability that $(r_P, r_D) = (L, \phi)$ occurs in Trial Stage given $t = h$. The other term can be similarly understood. This probability gives us P's expected payoff as proposed if $s_D = 1$.

Thus, P consults an expert if and only if the cost of consulting an expert is less than the net benefit from expert advice:

$$c \leq c_P^P \;=\; \mu e(1-p)(1-ep \cdot s_D) + (1-\mu)ep(1-e(1-p) \cdot s_D) \tag{2}$$

where (i) the subscript P in the threshold c_P^P indicates that this is the threshold for P, and (ii) the superscript P in c_P^P indicates that BOP is on P. As shown above, D's counteracting effort reduces P's incentive to consult an expert: c_P^P is larger when $s_D = 0$ than when $s_D = 1$. Thus, as D becomes *more* aggressive in consulting an expert, P becomes *less* aggressive.

As the event of D's winning is the complement of P's winning, it is straightforward to calculate D's expected payoff as follows:

- $\underbrace{1-\{\mu e(1-p)+(1-\mu)ep\} \cdot s_P}_{\text{prob. of D's winning}}$ if he does not consult an expert, or
- $\underbrace{1-\{\mu e(1-p)(1-ep)+(1-\mu)ep(1-e(1-p))\} \cdot s_P}_{\text{prob. of D's winning}} - c$ if he consults an expert

where $s_P = 1$ if P contacts an expert and $s_P = 0$ otherwise. Thus, D's behavior can be also summarized by an appropriate threshold c_D^P such that D consults an expert if and only if $c \leq c_D^P$ where the superscript and subscript in c_D^P have similar meaning as before. Table 1 summarizes the simultaneous game that the litigants play in Pretrial Stage.

Note that D never consults an expert when P does not because $c_D^P = 0$ if $s_P = 0$. This finding shows that D's motive for consulting an expert is primarily to counteract his opponent's evidence when he does not bear BOP. Thus, as P becomes *more* aggressive in consulting an expert, D also becomes *more* aggressive.

3.2.2 Prior in favor of P

In this subsection, I assume $\mu < \frac{1}{2}$. It is routine to check that P's expected payoff is given as follows:

- 0 if he does not consult an expert, or
- $\underbrace{\mu e(1-p) + (1-\mu)ep}_{= eP(x_P = L) = \text{prob. of P's winning}} - c$ if he consults an expert.

Note that if P obtains and reveals favorable evidence, he always wins in Trial Stage regardless of D's action. In contrast to the previous case, D cannot counteract P's evidence because P enjoys a favorable prior assessment for his cause: P wins not only under $(r_P, r_D) = (L, \phi)$, but also under $(r_P, r_D) = (L, H)$ because J's posterior belief is equal to $\mu < \frac{1}{2}$ that leads to P's winning. Thus, P consults an expert if and only if

$$c \leq c_P^P = \mu e(1-p) + (1-\mu)ep. \tag{3}$$

It is also straightforward to obtain D's expected payoff as follows:

- $\underbrace{1 - \{\mu e(1-p) + (1-\mu)ep\} \cdot s_P}_{= 1 - eP(x_P = L)s_P = \text{prob. of D's winnng}}$ if he does not consult an expert, or
- $\underbrace{1 - \{\mu e(1-p) + (1-\mu)ep\} \cdot s_P}_{= 1 - eP(x_P = L)s_P = \text{prob. of D's winnng}} - c$ if he consults an expert.

It is clear that D never wants to consult an expert. Note that D's winning does not depend on his action but only on P's: whenever P reveals $x_P = L$, P wins regardless of D's presentation (i.e., P wins under $(r_P, r_D) = (L, H)$ and $(r_P, r_D) = (L, \phi)$); and whenever P cannot reveal $x_P = L$, P loses regardless of D's presentation (i.e., P loses under $(r_P, r_D) = (\phi, H)$ and $(r_P, r_D) = (\phi, \phi)$).[19] Thus, D rationally chooses not to consult any expert, leaving the final verdict dependent on P's choice.

3.3 Equilibrium

Note that the allocation of BOP depends on J's belief regarding which litigant consulted an expert. Conversely, when the litigants choose whether to consult an expert, they take BOP (and therefore J's belief about their own behavior) as given. In an equilibrium, the BOP allocation must be consistent with the litigants' strategies. I now turn to this issue and find the equilibria in DI.

[19] Remember that P loses under $(r_P, r_D) = (\phi, \phi)$ because I assume that BOP is on P.

It turns out that there exist two types of equilibria in DI. The first type is called the *P-equilibrium* and the second type the *D-equilibrium*. The P-equilibrium is an equilibrium in which BOP is on P, whereas BOP falls on D in the D-equilibrium. I present the first main result in the following proposition. I omit the D-equilibrium result to save space, considering that it is symmetric.

Proposition 1. *There exist $\underline{c}$ and $\bar{c}$ such that $0 < \underline{c} < \bar{c}$ and the following is true.*

1. *If $\mu \geq \frac{1}{2}$, the P-equilibrium always exists, and*
   - $\bar{c} < c$: *no litigant consults an expert in the P-equilibrium*
   - $c \in (\underline{c}, \bar{c}]$: *only P consults an expert in the P-equilibrium*
   - $c \leq \underline{c}$: *both litigants consult an expert in the P-equilibrium*
2. *If $\mu < \frac{1}{2}$,*
   - $\bar{c} < c$: *the P-equilibrium does not exist*
   - $c \leq \bar{c}$: *the P-equilibrium, in which only P consults an expert, exists if μ is close to $\frac{1}{2}$ or e is close to 1*

Proof. See the Appendix. □

The results are intuitive. Consider the first part in which $\mu \geq \frac{1}{2}$. When the cost of consulting an expert is large, no litigant is willing to incur a cost to consult an expert. In the P-equilibrium, this implies that J observes no evidence in Trial Stage and, knowing that no expert was involved in equilibrium, rules in favor of D because her posterior belief is equal to $\mu \geq \frac{1}{2}$. Although P knows that he will surely lose in Trial Stage, he refrains from using expert advice because it is not worth the cost.

As c decreases, litigants are willing to consult an expert in equilibrium, and if c is sufficiently small, both litigants consult an expert for information. Note that P has a higher incentive to use an expert, and therefore only P uses expert advice for the intermediate range of c. Because BOP is on P, there is no chance for P to win if he does not consult an expert, whereas D still has a chance to win without using expert advice. Therefore, expert advice has a larger effect on P's expected payoff, generating the cost range in which only P consults an expert.

On the other hand, the existence of the P-equilibrium is not guaranteed under $\mu < \frac{1}{2}$, in which case P enjoys a favorable initial assessment toward his claim. Note that as the analysis of Pretrial Stage reveals, D has no incentive to consult an expert in this case because J's decision does not depend on D's presentation in Trial Stage. Thus, either P alone consults an expert under small c, or no litigants use expert advice under large c.

If c is large, no expert is consulted in equilibrium, and J therefore rules in favor of P after observing no evidence because $\mu(\phi, \phi) = \mu < \frac{1}{2}$. However, such a posterior belief is not consistent with BOP on P, and therefore the P-equilibrium does not exist in this situation. If c is small, P consults an expert, which increases J's equilibrium posterior belief $\mu(\phi, \phi)$ because J exercises skepticism toward P's silence in Trial Stage. Thus, if this increase in belief is sufficiently large, I have $\mu(\phi, \phi) \geq \frac{1}{2}$, which supports the existence of the P-equilibrium. Observe that this is possible if μ is large (i.e., μ is close to $\frac{1}{2}$) or e is large (i.e., e is close to 1). If μ is close to $\frac{1}{2}$, even a small degree of posterior updating will move J's equilibrium belief beyond $\frac{1}{2}$. If e is close to 1, P's silence is likely to have come from manipulation, which increases J's equilibrium posterior belief by a large degree.

4 Centralized Institution

In CI, J makes a decision directly consulting experts. Because J directly interacts with experts, she observes evidence from experts without any information loss arising from evidence distortion as in DI.[20] In the following analysis, I study J's choice of using expert advice and her final decision at trial under the assumption that $\mu \geq \frac{1}{2}$. As the analysis for the other case, $\mu < \frac{1}{2}$, is symmetric,[21] I omit the result to save space and to avoid unnecessary confusion.

First, suppose that J consults two experts. For comparison with DI, I denote the result from the first expert's investigation as r_P and that from the second expert's investigation as r_D. The following are the possible situations:

- $(r_P, r_D) = (H, H)$: D wins
- $(r_P, r_D) = (H, L)$ or (L, H): D wins ($\because$ posterior is equal to $\mu \geq \frac{1}{2}$)
- $(r_P, r_D) = (L, L)$: P wins
- $(r_P, r_D) = (H, \phi)$ or (ϕ, H): D wins
- $(r_P, r_D) = (L, \phi)$ or (ϕ, L): P wins
- $(r_P, r_D) = (\phi, \phi)$: D wins ($\because$ posterior is equal to $\mu \geq \frac{1}{2}$)

[20] Evidence distortion could arise in CI as well. For this possibility, see Dewatripont and Tirole (1999) and the extensions of their model, including Palumbo (2001, 2006), Iossa and Palumbo (2007), Deffains and Demougin (2008), and Kim (2014b), which adopt an incomplete contract framework.

[21] Proposition 2 presents the result for the case of $\mu \geq \frac{1}{2}$ and is summarized by the thresholds $\underline{c}_J$ and $\bar{c}_J$. The result for $\mu < \frac{1}{2}$ can also be summarized by appropriate thresholds with the same structure as in Proposition 2.

In contrast to DI, there is no indirect evidence that can be collected from the no-evidence event, (ϕ, ϕ), because it simply indicates that both experts are uninformed. Thus, J has no information under the event (ϕ, ϕ), and her posterior belief therefore is equal to her prior belief. Because I assume $\mu \geq \frac{1}{2}$, D wins under such a situation.

Anticipating these results, J's expected payoff when consulting two experts is

$$\begin{aligned}
\pi_J^2 &= \underbrace{P(H,H)\mu(H,H) + 2P(H,L)\mu + P(L,L)(1-\mu(L,L))}_{\text{exp. payoff from observing both signals}} \\
&\quad + \underbrace{2P(H)\mu(H) + 2P(L)(1-\mu(L))}_{\text{exp. payoff from observing only one signal}} \\
&\quad + \underbrace{(1-e)^2\mu}_{\text{exp. payoff from observing no signal}} \\
&\quad - \underbrace{2c}_{\text{cost of expert advice}} \\
&= e^2(\mu p^2 + 2p(1-p)\mu + (1-\mu)p^2) + 2e(1-e)(\mu p + (1-\mu)p) + (1-e)^2\mu - 2c
\end{aligned}$$

$$\begin{aligned}
P(j,j') &: \quad \text{probability of } (r_P, r_D) = (j, j') \text{ for } j, j' \in \{H, L\} \\
P(j) &: \quad \text{probability of } (r_P, r_D) = (j, \phi) \text{ for } j \in \{H, L\} \\
\mu(j,j') &: \quad \text{posterior from } (r_P, r_D) = (j, j') \text{ for } j, j' \in \{H, L\} \\
\mu(j) &: \quad \text{posterior from } (r_P, r_D) = (j, \phi) \text{ for } j \in \{H, L\}
\end{aligned}$$

More precisely, consider the first term in J's expected payoff. The probability to observe (H, H) is

$$P(H,H) = e^2(\mu p^2 + (1-\mu)(1-p)^2).$$

Given that the hidden evidence is (H, H), J believes that the probability of $t = h$ is

$$\mu(H,H) = \frac{\mu p^2}{\mu p^2 + (1-\mu)(1-p)^2} > \frac{1}{2}.$$

Thus, J rules in favor of D, expecting to obtain

$$\mu(H,H) \times 1 + (1 - \mu(H,H)) \times 0$$

which is equal to $\mu(H, H)$. Multiplying $P(H, H)$ and $\mu(H, H)$ provides us with the first term $e^2\mu p^2$. Other terms can be similarly understood.

Second, suppose that J consults only one expert.[22] The following are the possible situations:

[22] I denote the information from this expert as r_P without loss of generality.

- $r_P = H$: D wins
- $r_P = L$: P wins
- $r_P = \phi$: D wins ($\because$ posterior is equal to $\mu \geq \frac{1}{2}$)

Anticipating these results, J's expected payoff from consulting only one expert is

$$\begin{aligned}
\pi_J^1 &= \underbrace{P(H)\mu(H) + P(L)(1-\mu(L))}_{\text{exp. payoff from observing one signal}} \\
&\quad + \underbrace{(1-e)\mu}_{\text{exp. payoff from observing no signal}} \\
&\quad - \underbrace{c}_{\text{cost of expert advice}} \\
&= e(\mu p + (1-\mu)p) + (1-e)\mu - c
\end{aligned}$$

where $P(j)$ and $\mu(j)$ for $j \in \{H, L\}$ are as defined previously.

Finally, if J consults no experts, she simply rules in favor of D according to her prior belief, and therefore her expected payoff is given by

$$\pi_J^0 = \mu.$$

By comparing these expected payoffs, I can identify the conditions under which J consults two, only one, or no experts, which is summarized in the following proposition.

Proposition 2. *There exist $\underline{c}_J > 0$, $\bar{c}_J > 0$, and $\overline{\mu} \in (\frac{1}{2}, p)$ such that the following is true.*

1. *When $\mu \in [\frac{1}{2}, \overline{\mu})$, the optimal number of experts for J is*
   - *0 if $\bar{c}_J < c$*
   - *1 if $c \in (\underline{c}_J, \bar{c}_J] \neq \emptyset$*
   - *2 if $c \leq \underline{c}_J$*
2. *When $\mu \geq \overline{\mu}$, the optimal number of experts for J is*
   - *0 if $\frac{1}{2}(\underline{c}_J + \bar{c}_J) < c$*
   - *2 if $c \leq \frac{1}{2}(\underline{c}_J + \bar{c}_J)$*

Proof. See the Appendix. □

The first part of the proposition presents an intuitive result: as information from experts is valuable, a lower cost induces J to consult more experts. In particular, if the cost lies in the intermediate range, J consults only one expert for information. On the other hand, the second part demonstrates that it is never optimal for J to consult only one expert under certain situations. The intuition is straightforward: if J's prior belief is sufficiently strong, information from only one expert is not persuasive enough, and J therefore wants to hear from at least two experts if she chooses to consult any expert.

5 Comparison

In this section, I compare the two institutional arrangements for expert testimony and establish two main results. First, I show that the cost threshold for no-expert is higher in DI than in CI. In other words, the litigants consult an expert in DI even when J is reluctant to do so in CI when the cost of consulting an expert is relatively high. This finding supports the claim by Posner (1988), who argues that one of the merits of using the decentralized procedure is the high initiative of the litigants in shaping the fact-finding process. Second, I show that, given the same number of experts consulted under both institutions, the final decision by J is more accurate in CI than in DI. This finding highlights the concerns echoed by Tullock (1988), who criticizes decentralized legal systems for production and presentation of misleading information by the litigants, to the detriment of the final verdict's accuracy.

5.1 Incentive to Consult Experts

The following proposition demonstrates that the no-expert threshold is higher under both types of equilibria of DI than under CI.

Proposition 3. *The no-expert threshold from the P-equilibrium in DI is higher than the thresholds in CI:* $\max\{\underline{c}_J, \bar{c}_J\} < \bar{c}$. *The same result holds for the D-equilibrium in DI and CI.*

Proof. See the Appendix. □

To understand the intuition, supposing $\mu \geq \frac{1}{2}$, it is instructive to compare the net benefit from consulting one expert rather than none under both institutions. In CI, J's net benefit from consulting one expert rather than none is given by[23]

$$e((1-\mu)p - \mu(1-p)). \tag{4}$$

[23]In the proof of Proposition 2, J's net benefit from consulting one expert rather than none is given by $\bar{c}_J$. After rearranging terms, $\bar{c}_J$ can be expressed as (4).

The first term inside the parentheses, $(1-\mu)p$, is the probability of observing the low signal when the true state is low. Because J rules in favor of P upon observing the low signal, this is "good news" leading to correct decision-making. However, the second term inside the parentheses, $\mu(1-p)$, indicates "bad news" leading to an incorrect decision: this is the probability of observing the low signal when the true state is high. Because the low signal induces J to rule in favor of P, it generates errors, which reduces J's incentive to consult an expert.

In contrast, in DI, finding the low signal is always good news for P, whose net benefit from consulting an expert is given by[24]

$$e((1-\mu)p + \mu(1-p)). \tag{5}$$

As is obvious from the expression above, finding the low signal is always good news for P, because the low signal is favorable to his cause and he wants to win regardless of the true state. This effect increases a litigant's incentive to consult an expert relative to J's, and therefore an expert operates under a larger range of the cost parameter in DI than in CI.

The discussion above suggests that a litigant, who is a *partisan agent*, has a higher incentive to consult an expert than a trier of fact, who is an *impartial agent*. Related results are reported in the literature. In a setting with heterogenous prior beliefs, Che and Kartik (2009) show that an agent whose prior belief is different from the decision-maker's has a stronger incentive to search for information, which induces the decision-maker to optimally hire such an agent despite communication problems. Whereas their model demonstrates that the decision-maker always prefers a partisan agent to a neutral one, my model identifies the conditions under which using a partisan agent (i.e., using DI) is better than using a neutral agent (i.e., using CI), and vice versa.

Dewatripont and Tirole (1999) ask related questions in a principal-agent setting in which an uninformed principal acquires information through agents before making a decision. Their main results show that using two agents (termed *advocacy*), each collecting information for a competing cause, generates information with lower agency costs than having one agent collect information for both competing causes (termed *nonpartisanship*). As the agents are rewarded based on the principal's final decision in their model (termed *decision-based rewards*), the agent in charge of conflicting tasks is reluctant to provide information for both causes because if he does so, the two units of conflicting information will lead to the status quo, generating no payment to the agent. The principal does not have such a problem if she hires two agents and makes each agent a "partisan" to a cause, which generates the value of using a

[24] In the proof of Proposition 1, P's net benefit from consulting an expert is given by $\bar{c}$. After rearranging terms, $\bar{c}$ can be expressed as (5).

partisan agent in their model. Note that the agent under the nonpartisanship in their model is not impartial in the sense that he wants to move the principal's decision away from the status quo. Thus, their main result is about a comparison between two different types of partisan preferences of the agents induced by the decision-based rewards, whereas Proposition 3 involves a comparison of the partisan and impartial preferences of the agents.

In contrast to these findings, Dur and Swank (2005) demonstrate that the bias of the agent may discourage his search effort in a soft-information framework. This is because when an agent recommends a policy to the decision-maker, a strongly biased agent makes a recommendation following his bias, not his information. Thus, as the bias of the agent increases, he values information less and therefore puts less effort in information collection. Note that they obtain this result because an agent's recommendation can be different from his information, which is possible under a soft-information framework. This finding suggests that the nature of information (i.e., hard versus soft) is an important factor in studying an agent's incentive for information search. For a general discussion regarding information search incentives, see Sobel (2013).

In general, a growing body of literature investigates the trade-off between the collection and communication of information. On the one hand, for better communication between an informed agent and an uninformed decision-maker, it is necessary to reduce the degree of conflict of interest between them. On the other hand, it is often observed that non-congruent preferences create incentives for agents to exert more effort for information. The current paper is in line with the extant literature in that it shows that a partisan agent has a higher incentive to consult an expert than an impartial agent, because the partisan agent's net benefit from additional information is higher.

5.2 Information Loss from Evidence Distortion

Both legal institutions, DI and CI, generate errors because J faces uncertainty in decision-making. To examine which system is better at reducing mistakes, I formally define the measure of accuracy as follows:

$$E = \mu\alpha + (1-\mu)\beta \tag{6}$$

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. With such an interpretation, the measure in (6) is the average of the two types of errors. In the subsequent analysis, I calculate

E from each legal institution and compare them.

Consider the cost range in which only one expert is consulted in both institutions. First, suppose $\mu \geq \frac{1}{2}$. Then, the error from the P-equilibrium in DI is calculated as[25]

$$\begin{aligned} E_P^1 &= \mu\alpha + (1-\mu)\beta \\ &= \mu P(\text{P wins}|h) + (1-\mu)P(\text{D wins}|l) \\ &= \mu e P(L|h) + (1-\mu)(1-e+eP(H|l)) \\ &= \mu e(1-p) + (1-\mu)(1-e+e(1-p)) \end{aligned}$$

More precisely, α is the probability that J incorrectly rules in favor of P. Note that only P consults an expert, and he wins if and only if he can present favorable evidence for his cause to J. Given $t = h$, such an event occurs with probability $eP(L|h)$, which is α in DI. Similarly, given $t = l$, D wins if and only if P cannot present favorable evidence to J. Thus, the probability for such an event is equal to $1 - e + eP(H|l)$, which is β in DI.

The error in CI is given by

$$\begin{aligned} E_J^1 &= \mu\alpha + (1-\mu)\beta \\ &= \mu P(\text{P wins}|h) + (1-\mu)P(\text{D wins}|l) \\ &= \mu e P(L|h) + (1-\mu)(1-e+eP(H|l)) \\ &= \mu e(1-p) + (1-\mu)(1-e+e(1-p)). \end{aligned}$$

By consulting only one expert, J observes H, L, or ϕ as a result of the expert's investigation. Note that D wins under ϕ because there is no evidence distortion in CI and therefore J's posterior belief under ϕ is equal to $\mu \geq \frac{1}{2}$. Thus, P wins if and only if J observes $x = L$ from the expert, which implies $\alpha = eP(L|h)$ and $\beta = (1 - e + eP(H|l))$.

It is interesting to find that the two institutions generate the same amount of mistakes, i.e., $E_P^1 = E_J^1$. The intuition is as follows. In DI, P distorts evidence submitted to J by suppressing unfavorable evidence for his cause. Thus, J only observes the low signal ($r_P = L$) or nothing ($r_P = \phi$) from P. If J observes the low signal, she "correctly"—in the sense that her decision is based on all the available evidence—rules in favor of P. If P remains silent, J reasons that there are two possibilities. First, if P is silent due to a manipulation motive (i.e., hiding $x_P = H$), the correct ruling should be to rule in favor of D. Second, if P is silent simply because he is uninformed, J's posterior belief must be equal to $\mu \geq \frac{1}{2}$, and therefore the correct ruling should be again to rule in favor of D. Thus, in any case, the optimal decision for J under the no-evidence event is to rule in favor of D, which is exactly what J does in

[25]The subscript P in E_P^1 clarifies that this is the error from the P-equilibrium in DI.

the P-equilibrium of DI. This finding demonstrates that evidence distortion is not necessarily detrimental for the decision-making authority, at least when the decision is binary.

Second, suppose $\mu < \frac{1}{2}$. If the P-equilibrium with P consulting an expert exists, its error takes the same formula as previously calculated. In contrast, the error in CI is given by

$$\begin{aligned} E_J^1 &= \mu\alpha + (1-\mu)\beta \\ &= \mu P(\text{P wins}|h) + (1-\mu)P(\text{D wins}|l) \\ &= \mu(eP(L|h) + 1 - e) + (1-\mu)eP(H|l) \\ &= \mu(e(1-p) + 1 - e) + (1-\mu)e(1-p). \end{aligned}$$

When the prior belief is against D, the no-evidence event induces J to rule in favor of P. Thus, P wins unless J observes the high signal from the expert, which implies $\alpha = eP(L|h) + 1 - e$ and $\beta = eP(H|l)$. Since it immediately follows that E_J^1 is smaller than E_P^1 in this case, I obtain the following proposition.[26]

Proposition 4. *Suppose that only one expert is consulted in both institutions.*

1. $\mu \geq \frac{1}{2}$*:* $E_P^1 = E_J^1$*, and* $E_D^1 > E_J^1$ *if the D-equilibrium exists.*

2. $\mu < \frac{1}{2}$*:* $E_D^1 = E_J^1$*, and* $E_P^1 > E_J^1$ *if the P-equilibrium exists.*

Although evidence distortion in the P-equilibrium of DI is not detrimental to the decision-making authority when $\mu \geq \frac{1}{2}$, it is when $\mu < \frac{1}{2}$. If P remains silent in Trial Stage of DI, the P-equilibrium requires J to rule in favor of D. This decision is incorrect if P is silent due to lack of evidence, because in that case J's posterior should be equal to $\mu < \frac{1}{2}$, leading to P's winning. Thus, the impartiality of CI works to reduce decision-making errors relative to DI in such a situation.

Now consider the cost range in which two experts are consulted in both institutions. For the P-equilibrium (the D-equilibrium), this is possible only when $\mu \geq \frac{1}{2}$ ($\mu < \frac{1}{2}$). Let E_P^2 (E_D^2) and E_J^2 denote the errors from the P-equilibrium (the D-equilibrium) in DI and CI, respectively. It turns out that when two experts are consulted in both systems, the decision-making error is always strictly smaller under CI because there is no evidence distortion in the system. To see this more clearly, consider the situations in which there is no direct evidence in the P-equilibrium. The event $(r_D, r_P) = (\phi, \phi)$ occurs under the following four possibilities: $(x_D, x_P) = (L, H)$, (ϕ, H), (L, ϕ), or (ϕ, ϕ). For example, the "correct" decision under $(x_D, x_P) = (L, \phi)$ is to rule in favor of P. However, J is induced to rule in favor of D in such a situation because the litigants present $(r_D, r_P) = (\phi, \phi)$, under which D wins in the

[26] As the analysis for the D-equilibrium part is symmetric, I present the result without the proof.

P-equilibrium. Thus, J cannot optimally make use of the available evidence because of the litigants' evidence distortion, which increases the error under DI.

Proposition 5. *Suppose that two experts are consulted in both institutions. If* $\mu \geq \frac{1}{2}$, $E_P^2 > E_J^2$. *If* $\mu < \frac{1}{2}$, $E_D^2 > E_J^2$.

Proof. See the Appendix. □

These results suggest that the benefit of DI lies in the interested parties' high initiatives, which induce litigants to use expert information for a larger range of the cost parameter than J does in CI. However, the implicit cost of DI, other than the cost of experts, is an information loss due to evidence distortion by the litigants. If the same number of experts is consulted in both institutions, DI generates more mistakes than CI due to evidence distortion by the litigants.

6 Discussion

Within the framework of a persuasion game with endogenous information, this paper examines the relative merits of two institutions, CI and DI. The main results demonstrate that there is a trade-off: although DI supplies the fact finder with valuable information more often, it also suffers from an information loss due to its competitive nature.

The analysis suggests that the ranking of the two institutions in terms of accuracy depends on the cost of consulting an expert. If the cost is large, the decision-making accuracy is expected to be higher in DI than in CI because expert information is utilized only in the former institution. In contrast, CI is expected to be superior when the cost is small: if the same amount of expert information is utilized in the two systems, the decision-making accuracy is expected to be higher in CI because there is no information loss in the system.

Although proponents for policy reforms who encourage the trier of fact to appoint her own experts raise valid concerns, one should keep in mind that the cost of using expertise may affect the system's performance. If it is costly to make use of the knowledge possessed by experts in specific domains, society may observe a *decline* in the usage of expert information in trial courts as a result of policy reforms, which could lead to less-accurate decision-making by judges. I conclude this paper by discussing the model's results and suggesting directions for future research.

6.1 Continuous Decision

The binary decision assumption is crucial in simplifying the analysis. If J's decision becomes continuous in DI, an immediate challenge is that checking the consistency of beliefs becomes a daunting task. To describe this point, let us suppose that J's optimal decision d^* under (r_P, r_D) is equal to her posterior belief.[27] Then, the following are the four possible situations in Trial Stage:

1. $(r_P, r_D) = (L, \phi)$: $d^* = \mu(L, \phi)$
2. $(r_P, r_D) = (\phi, H)$: $d^* = \mu(\phi, H)$
3. $(r_P, r_D) = (L, H)$: $d^* = \mu$
4. $(r_P, r_D) = (\phi, \phi)$: $d^* = \mu(\phi, \phi)$

Compared to the basic model, there are two main changes in this extended formulation: (i) the magnitude of J's posterior belief becomes more important, and (ii) J's belief about the litigants' behavior in Pretrial Stage becomes more important. For example, consider the first situation, in which J observes $(r_P, r_D) = (L, \phi)$. In the basic model, J rules in favor of P, and her decision does not depend on the magnitude of her posterior belief. In contrast, in this extended formulation, J's decision crucially depends on the strength of her belief about the true state: if J strongly believes that the true state is in favor of P's claim, her decision becomes more favorable toward P. Furthermore, in contrast to the basic model, J's decision depends on J's belief about the litigants' behavior in Pretrial Stage: d^* can be high or low depending on whether D also consulted an expert in Pretrial Stage. This second effect was present only in the fourth situation in the basic model, but it operates in other situations as well in this extended formulation. I leave a more careful analysis of this extended model to future research.

6.2 Soft Information

Another important assumption in the current model is that information is hard. Thus, the litigants in DI may conceal evidence if it is harmful to their causes but cannot falsify the evidence presented to J. Although models with hard information seem reasonable in a trial setting in which the falsification of evidence imposes large penalties upon the party, an interesting research area is to study the ways in which the possibility of falsification may affect the litigants' strategies along with the trial outcome. For example, see Emons and Fluet (2009a,b), who study a litigation game in which players may falsify their information by paying some cost.

The current model is not well-suited to study the effect of soft information, because if information is soft, a litigant has no incentive to consult an expert: a litigant always wants

[27] That is, I assume that J's objective function takes the form of the quadratic function $-(d-t)^2$, where $d \in \mathbb{R}$ is J's decision and $t \in \{0, 1\}$ is the true state.

to present favorable information to J in Trial Stage because he wants to win regardless of the true state, and therefore he does not need to consult an expert in Pretrial Stage. In order to provide a litigant with an incentive to seek expert advice within the soft-information framework, the model may need to be extended in a way that the litigant's preference depends on the true state.[28] In such a situation, the litigant wants to obtain knowledge about the true state before presenting any soft information to J, which generates the value of consulting an expert.

It is not clear whether the main results still hold in this soft-information framework. In particular, as discussed in Section 5.1 in light of the work by Dur and Swank (2005), it is possible that a litigant's strong preference bias discourages his incentive to consult an expert. If it is so, the degree of verifiability of evidence at trial will be an important factor in the trade-off between the two institutions. A careful analysis of this issue awaits future research.

6.3 Cost and Deterrence

The focus of the main results in comparing the two institutions is the accuracy of J's decision. However, there are at least two other important characteristics of legal institutions: cost and deterrence.

First, let us consider the cost effect in comparing the institutions.[29] Proposition 3 suggests that for the high-cost range, DI is likely to be superior to CI in terms of accuracy because expert advice is utilized only in the former institution. As more expert advice means more information for J's decision-making, leading to higher accuracy, DI is expected to perform better than CI as far as accuracy is concerned. However, as more information from expert advice can be obtained only by spending more resources for consulting an expert, the litigants' strong incentive to obtain information is not necessarily beneficial for society. In light of this trade-off between accuracy and cost, the societal preference over legal outcomes becomes important: if a society attaches more value to accuracy, it may prefer DI to CI, and vice versa.[30] In contrast, Propositions 4 and 5 suggest that we need not be concerned about

[28]For example, a litigant may ask for a high decision when the true state is moderate, whereas he may ask for a moderate decision when the true state is low. Such preferences may arise due to a litigant's moral concerns, which keep him from deviating too much from the true state.

[29]Posner argues that accuracy and cost are the two most important criteria in comparing legal systems (Posner, 1999, p.1542).

[30]Thus, the existence of different legal institutions may reflect preference differences across societies. Kaplow (1994) notes that "[one] might go so far as to say that a large portion of the rules of civil, criminal, and administrative procedure and rules of evidence involve an effort to strike a balance between accuracy and legal costs." Presumably, in pursuit of such a balance, certain societies might have embraced a decentralized way of solving information provision problems, whereas others have adopted a centralized system. Thus, the current form of legal institutions in a society could be indicative of the preference of the society. In this vein, Demougin and Fluet (2005) conclude, studying the variation in the standard of proof across societies, that

such a trade-off for the low-cost range. As expert advice is expected to be utilized in both institutions, the evidence distortion problem in DI decreases the system's accuracy relative to CI in which such a problem does not exist. Thus, if the same amount of expert advice is used in both institutions, CI is superior to DI regardless of the cost consideration because a higher level of accuracy can be achieved in CI at the same amount of cost as in DI. This discussion suggests that the cost consideration operates in favor of CI in the current model.

A related issue is the effect of the rule that requires the litigants, rather than J, to pay the cost in CI. The main results do not change under this rule if J takes into account the cost borne by the litigants. If J does not consider the costs of expert advice, she will always consult two experts in CI regardless of the cost parameter, because expert advice is free information for J. This change could increase the accuracy of J's final decision at the expense of higher costs borne by the litigants, exhibiting the trade-off discussed above.

Second, let us consider how the two institutions perform differently in terms of deterrence. Deterrence is intimately related to accuracy because the trial outcomes influence an individual's choice of the primary behavior. Following Kaplow (1994), who argues that one benefit of accuracy is its deterrence effect, one could argue for a positive association between accuracy and deterrence: a higher level of accuracy is associated with a higher level of deterrence. Then, DI is expected to increase deterrence relative to CI for the high-cost range (Proposition 3), whereas CI is more likely to perform better in terms of deterrence for the low-cost range (Propositions 4 and 5). However, there is also a possibility of tension in pursuing these two legal outcomes simultaneously. For example, in a series of influential articles, Demougin and Fluet (2005, 2006, 2008) demonstrate that the common-law rules of proof maximizes deterrence at the expense of accuracy. Investigating the trade-off among different legal outcomes will be a fruitful future research topic.

6.4 Criminal vs. Civil Cases

In the main results, I assume that society is equally averse to both types of errors made by J. In criminal cases, however, society is typically more averse to Type I errors, wrongly convicting the innocent, than to Type II errors, wrongly acquitting the guilty. Thus, in general, the measure of accuracy can be defined as

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

common-law countries are more concerned with deterrence than accuracy whereas civil-law countries attach a greater weight to accuracy.

where $\lambda > 0$ measures the relative weight of Type I errors. In this extended formulation, criminal cases can be identified with $\lambda > 1$.

To understand how this change may affect the main results, consider E_P^1 and E_J^1. If $\mu \geq \frac{1}{2}$, I still have $E_P^1 = E_J^1$ because Type I errors (and Type II errors as well) under both institutions are the same. However, if $\mu < \frac{1}{2}$ (assuming the existence of the P-equilibrium in DI):

$$\begin{aligned} E_P^1 &= \mu\lambda \underbrace{e(1-p)}_{\text{Type I}} + (1-\mu)(\underbrace{1-e}_{(A)} + e(1-p)) \\ E_J^1 &= \underbrace{\mu\lambda\,(e(1-p) + \underbrace{1-e}_{(B)})}_{\text{Type I}} + (1-\mu)e(1-p) \end{aligned}$$

where Type I errors are larger in CI. Thus, if society is sufficiently verse to Type I errors (i.e., λ is large), I obtain $E_P^1 < E_J^1$ in contrast to the previous result.

This result follows from different BOP allocations across legal institutions. In the P-equilibrium of DI, P loses when his expert has no evidence (with probability $1-e$ in (A)) because he has BOP. In contrast, in CI, it is D who loses when J's expert fails to obtain hard evidence (with probability $1-e$ in (B)). Thus, the "implicit" BOP falls on D in CI, although no litigant explicitly bears BOP because J directly interacts with experts.

7 Appendix

7.1 Proof of Proposition 1

The proof consists of two steps. First, taking J's equilibrium belief as given, I find the players' equilibrium strategies. Second, I verify whether J's equilibrium belief is indeed consistent with the players' equilibrium strategies found in the first step. As the proof builds on the analysis from 3.1 and 3.2, I reproduce the main results of those subsections here as lemmas:

Lemma 1 (Section 3.1)**.** *In Trial Stage, the following is each player's behavior:*

1. *P only reports $x_P = L$ whenever possible*
2. *D only reports $x_D = H$ whenever possible*
3. *J's decision is given by*
   - $(r_P, r_D) = (L, \phi)$: *P wins*

- $(r_P, r_D) = (\phi, H)$: *D wins*
- $(r_P, r_D) = (L, H)$: *D wins if and only if* $\mu \geq \frac{1}{2}$
- $(r_P, r_D) = (\phi, \phi)$: *D wins if and only if* $\mu(\phi, \phi) \geq \frac{1}{2}$

Lemma 2 (Section 3.2)**.** *Assume BOP falls on P. In Pretrial Stage, the following is each player's behavior:*

1. *If* $\mu \geq \frac{1}{2}$*, there exists a pair* (c_P^P, c_D^P) *such that*

   - *P consults an expert if and only if* $c \leq c_P^P$*, and*
   - *D consults an expert if and only if* $c \leq c_D^P$

   where (i) c_P^P *and* c_D^P *depend on the litigants' choices, and (ii)* $c_D^P = 0$ *when P does not consult an expert.*

2. *If* $\mu < \frac{1}{2}$*, D does not consult an expert, and there exists* c_P^P *such that P consults an expert if and only if* $c \leq c_P^P$*.*

7.1.1 Step 1: Litigants' Equilibrium Strategies in Pretrial Stage

When BOP is on P, Lemma 2 demonstrates that three cases are possible: no litigants consult experts, P alone consults an expert, or both consult experts. In particular, D is never willing to consult an expert alone. The number of consulted experts under BOP on P depends on parameter values. To simplify the notations, let us define the following quantities:

$$\begin{aligned}
c_1 &= \mu e(1-p) + (1-\mu)ep \\
c_2 &= \mu e(1-p) + (1-\mu)ep - \{\mu e(1-p)(1-ep) + (1-\mu)ep(1-e(1-p))\} \\
c_3 &= \mu e(1-p)(1-ep) + (1-\mu)ep(1-e(1-p))
\end{aligned}$$

where (considering $\mu \geq \frac{1}{2}$ for interpretation[31])

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

Having defined these quantities, I can rank them according to their magnitudes. It is easy to show $\max\{c_2, c_3\} < c_1$. The following lemma shows $c_2 < c_3$:

[31] When $\mu < \frac{1}{2}$, P's net benefit from expert advice is c_1 regardless of D's choice, and D's net benefit from expert advice is 0 regardless of P's choice.

Lemma 3. $c_2 < c_3$.

Proof. Rearranging terms, I obtain

$$c_2 < c_3 \iff e < \frac{\mu - 2\mu p + p}{2p(1-p)} \equiv \hat{e}.$$

Observe that $\hat{e}$ is positive. The denominator of $\hat{e}$ is positive because $p \in (\frac{1}{2}, 1)$. The numerator of $\hat{e}$ is also positive because

$$0 \leq (\sqrt{\mu} - \sqrt{p})^2 = \mu - 2\sqrt{\mu p} + p < \mu - 2\mu p + p$$

where the last inequality holds because μp is a fraction.

To prove the lemma, it is sufficient to show $\hat{e} > 1$. To this end, let us define $g(p)$ as

$$\begin{aligned} g(p) &= \underbrace{\mu - 2\mu p + p}_{\text{numerator of } \hat{e}} - \underbrace{2p(1-p)}_{\text{denominator of } \hat{e}} \\ &= 2p^2 - 2\mu p - p + \mu. \end{aligned}$$

This function is an increasing function for $p \in (\frac{1}{2}, 1)$ because

$$\begin{aligned} g'(p) &= 4p - 2\mu - 1 \\ &> 4p - 2p - 1 \\ &= 2p - 1 \\ &> 0 \end{aligned}$$

where the second line follows because $\mu < p$ and the last inequality follows because $p > \frac{1}{2}$. As $g(\frac{1}{2}) = 0$, I conclude that $g(p) > 0$ for $p \in (\frac{1}{2}, 1)$. This completes the proof. $\square$

The litigants' behavior in Pretrial Stage depends on the size of the cost of using an expert. Assume $\mu \geq \frac{1}{2}$. If $c > c_1$, even when D does not use an expert, P's net benefit from using an expert is less than the cost. Thus, no litigant consults experts for information. If $c \in (c_2, c_1]$, it is straightforward to show that only P consults an expert. If $c \leq c_2$, both litigants consult an expert: D is willing to consult an expert when P consults an expert; because $c \leq c_2 < c_3$, the cost also rationalizes P's choice of consulting an expert. Thus, both litigants consult an expert when $c \leq c_2$.

Now assume $\mu < \frac{1}{2}$. In this case, D is never willing to consult an expert. Therefore, the only litigant who may consult an expert is P, and his choice depends on whether the net benefit of consulting an expert is larger than the cost of doing so. Thus, if $c \leq c_1$, P consults an expert, and does not do so otherwise. The following lemma summarizes these findings.

Lemma 4. *Suppose that BOP is on P in equilibrium. Then, the following are the litigants' equilibrium strategies in Pretrial Stage. If* $\mu \geq \frac{1}{2}$*,*

- $c_1 < c$*: no litigants consult an expert*
- $c \in (c_2, c_1]$*: only P consults an expert*
- $c \leq c_2$*: both litigants consult an expert*

If $\mu < \frac{1}{2}$*,*

- $c_1 < c$*: no litigants consult an expert*
- $c \leq c_1$*: only P consults an expert*

7.1.2 Step 2: Verifying Consistency of J's Equilibrium Belief

In the following, I examine whether the litigants' equilibrium strategies from Lemma 4 are consistent with BOP on P. As before, I separate the analysis into two parts, $\mu \geq \frac{1}{2}$ and $\mu < \frac{1}{2}$. I begin with the first part.

Prior in favor of D

Assume $\mu \geq \frac{1}{2}$. It turns out that any number of expert consulted by the litigants is consistent with the P-equilibrium, and therefore the P-equilibrium always exists:

1. If none or both of the litigants consult an expert for evidence, I have $\mu(\phi, \phi) = \mu \geq \frac{1}{2}$, which is consistent with BOP on P.
2. If only P consults an expert, I have $\mu(\phi, \phi) > \mu \geq \frac{1}{2}$, which is also consistent with BOP on P.

These findings are summarized in the following lemma:

Lemma 5. *If* $\mu \geq \frac{1}{2}$*, the P-equilibrium always exists, and*

- $c_1 < c$*: no litigants consult an expert in the P-equilibrium*
- $c \in (c_2, c_1]$*: only P consults an expert in the P-equilibrium*
- $c \leq c_2$*: both litigants consult an expert in the P-equilibrium*

Letting $\bar{c} \equiv c_1$ and $\underline{c} \equiv c_2$ proves the first part of Proposition 1.

Prior in favor of P

Now assume $\mu < \frac{1}{2}$. If $c > c_1$, P and D do not consult an expert for evidence, and therefore they present nothing to J. In equilibrium, J correctly anticipates the litigants' behavior, and this implies that $\mu(\phi, \phi) = \mu < \frac{1}{2}$. Thus, BOP cannot fall on P in this case, and therefore there is no P-equilibrium.

If $c \leq c_1$, P consults an expert but D does not. Thus, under the no-evidence event, J's belief is updated upward, i.e., $\mu(\phi, \phi) > \mu$. If the P-equilibrium is to exist, this updating must be enough so that $\mu(\phi, \phi)$ becomes larger than $\frac{1}{2}$ in spite of $\mu < \frac{1}{2}$. This is possible if μ is large (i.e., close to $\frac{1}{2}$) or e is large (i.e., close to 1). Note that $\mu(\phi, \phi)$ in this case is given by (1), which can be easily verified to be increasing in μ and e. Because I have $\mu(\phi, \phi) > \frac{1}{2}$ under $\mu = \frac{1}{2}$, by continuity, I also have $\mu(\phi, \phi) > \frac{1}{2}$ when μ is sufficiently close to $\frac{1}{2}$. Also, it is straightforward to obtain $\mu(\phi, \phi) > \frac{1}{2}$ from (1) under $e = 1$. Thus, again by continuity, I have $\mu(\phi, \phi) > \frac{1}{2}$ for sufficiently large e.

These findings are summarized in the following lemma:

Lemma 6. *If $\mu < \frac{1}{2}$,*

- $c_1 < c$*: the P-equilibrium does not exist*
- $c \leq c_1$*: the P-equilibrium, in which only P consults an expert, exists if μ is close to $\frac{1}{2}$ or e is close to 1*

Letting $\bar{c} \equiv c_1$ proves the second part of Proposition 1.

7.2 Proof of Proposition 2

J consults one expert rather than none if $\pi_J^1 \geq \pi_J^0$, or equivalently, if the cost is less than the net benefit of consulting an expert:

$$\begin{aligned} c \leq \bar{c}_J &= e(\mu p + (1-\mu)p) + (1-e)\mu - \mu \\ &= e(p - \mu) \\ &> 0. \end{aligned}$$

Similarly, if the cost is such that

$$\begin{aligned} c \leq \underline{c}_J &= e^2(\mu p^2 + 2p(1-p)\mu + (1-\mu)p^2) + 2e(1-e)(\mu p + (1-\mu)p) + (1-e)^2\mu \\ &\quad -[e(\mu p + (1-\mu)p) + (1-e)\mu] \\ &= (1-e) \cdot \underbrace{e(p-\mu)}_{(A)>0} \quad + \quad e \cdot \underbrace{ep(1-p)(2\mu-1)}_{(B)\geq 0 \quad \because \mu \geq \frac{1}{2}} \end{aligned}$$

$$> \quad 0$$

then J consults two experts rather than only one.

Lastly, if the cost is such that

$$\begin{aligned}
c &\leq \frac{1}{2}\{\underbrace{e^2(\mu p^2 + 2p(1-p)\mu + (1-\mu)p^2) + 2e(1-e)(\mu p + (1-\mu)p) + (1-e)^2\mu}_{(1)} - \underbrace{\mu}_{(2)}\} \\
&= \frac{1}{2}\{\underbrace{e^2(\mu p^2 + 2p(1-p)\mu + (1-\mu)p^2) + 2e(1-e)(\mu p + (1-\mu)p) + (1-e)^2\mu}_{(1)} \\
&\quad - \underbrace{[e(\mu p + (1-\mu)p) + (1-e)\mu]}_{(3)} + \underbrace{[e(\mu p + (1-\mu)p) + (1-e)\mu]}_{(3)} - \underbrace{\mu}_{(2)}\} \\
&= \frac{1}{2}\left(\underbrace{\underline{c}_J}_{=(1)-(3)} + \underbrace{\bar{c}_J}_{=(3)-(2)}\right) \\
&> 0
\end{aligned}$$

then J consults two experts rather than none.

Rearranging $\underline{c}_J$ and $\bar{c}_J$, I obtain

$$\underline{c}_J < \bar{c}_J \iff \mu < \frac{2p - p^2}{1 + 2p(1-p)} \equiv \overline{\mu}$$

where it is straightforward to show $\bar{\mu} \in (\frac{1}{2}, p)$.

First, consider the case of $\underline{c}_J \geq \bar{c}_J$. If $c > \bar{c}_J$, no expert is better than 1 expert for J. If $c \leq \bar{c}_J$, 1 expert is better than no expert, and 2 experts are better than 1 expert because $c \leq \bar{c}_J \leq \underline{c}_J$. Thus, J never consults only one expert in this case, and therefore the only issue for J is whether to consult two experts or none. Hence, J consults two experts when $c \leq \frac{1}{2}(\underline{c}_J + \bar{c}_J)$ and she consults no expert otherwise, which proves the second part of the proposition. The first part can also be proved similarly.

7.3 Proof of Proposition 3

Let us compare the no-expert threshold from the P-equilibrium in DI and the thresholds from CI. Consider $\mu \geq \frac{1}{2}$. Comparing $\bar{c}$ and $\bar{c}_J$, I obtain

$$\bar{c} = c_1 = e((1-\mu)p + \mu(1-p)) > e((1-\mu)p - \mu(1-p)) = e(p - \mu) = \bar{c}_J.$$

Subtracting $\underline{c}_J$ from $\bar{c}$, I obtain

$$\begin{aligned}
\bar{c} - \underline{c}_J &= c_1 - \underline{c}_J \\
&= e(\mu(1-p) + (1-\mu)p) - \{(1-e)e(p-\mu) + e^2 p(1-p)(2\mu - 1)\} \\
&= e(\mu + p - 2\mu p - e(p^2 + 2\mu p(1-p) - p) - (1-e)(p-\mu)) \\
&= e(\underbrace{2\mu(1-p)(1-ep)}_{+} + e(\underbrace{p-p^2}_{+} + \underbrace{p-\mu}_{+})) \\
&> 0
\end{aligned}$$

Next, consider $\mu < \frac{1}{2}$. In this case, $\bar{c}_J$ and $\underline{c}_J$ are given by

$$\begin{aligned}
\bar{c}_J &= e(\mu p - (1-\mu)(1-p)) \\
\underline{c}_J &= e^2(\mu p^2 + 2p(1-p)(1-\mu) + (1-\mu)p^2) + 2e(1-e)(\mu p + (1-\mu)p) \\
&\quad +(1-e)^2(1-\mu) - e(\mu p + (1-\mu)p) - (1-e)(1-\mu)
\end{aligned}$$

Subtracting $\bar{c}_J$ from $\bar{c}$, I obtain

$$\begin{aligned}
\bar{c} - \bar{c}_J &= e((1-\mu)p + \mu(1-p)) - e(\mu p - (1-\mu)(1-p)) \\
&= e((1-\mu)p + \mu(1-p) - \mu p + (1-\mu)(1-p)) \\
&= e(1 - 2\mu p) \\
&> 0
\end{aligned}$$

where the last inequality holds because $\mu < \frac{1}{2}$ and $p < 1$.

Subtracting $\underline{c}_J$ from $\bar{c}$, I obtain

$$\begin{aligned}
\bar{c} - \underline{c}_J &= e((1-\mu)p + \mu(1-p)) - \{e^2(\mu p^2 + 2p(1-p)(1-\mu) + (1-\mu)p^2) \\
&\quad +2e(1-e)(\mu p + (1-\mu)p) + (1-e)^2(1-\mu) - e(\mu p + (1-\mu)p) - (1-e)(1-\mu)\} \\
&= e(\underbrace{(1-e)}_{+}\underbrace{(1-2\mu p)}_{+} + ep^2\underbrace{(1-2\mu)}_{+} + e\mu) \\
&> 0
\end{aligned}$$

Thus, $\bar{c}$ from the P-equilibrium in DI is higher than $\bar{c}_J$ and $\underline{c}_J$ in CI. As the proof for the D-equilibrium part is completely symmetric, this completes the proof.

7.4 Proof of Proposition 5

First, assume $\mu \geq \frac{1}{2}$. In the P-equilibrium with two experts, the error can be calculated as

$$\begin{aligned} E_P^2 &= \mu P(\text{P wins}|h) + (1-\mu)P(\text{D wins}|l) \\ &= \mu e(1-p)(1-e+e(1-p)) + (1-\mu)(1-ep(1-e+ep)). \end{aligned}$$

If J consults two experts in CI, the error is given by

$$\begin{aligned} E_J^2 &= \mu P(\text{P wins}|h) + (1-\mu)P(\text{D wins}|l) \\ &= \mu(e^2(1-p)^2 + 2e(1-e)(1-p)) + (1-\mu)(1-e^2p^2 - 2e(1-e)p) \end{aligned}$$

Then, subtracting E_J^2 from E_P^2, I obtain

$$\begin{aligned} E_P^2 - E_J^2 &= \mu e(1-p)(1-e+e(1-p)) + (1-\mu)(1-ep(1-e+ep)) \\ &\quad -[\mu(e^2(1-p)^2 + 2e(1-e)(1-p)) + (1-\mu)(1-e^2p^2 - 2e(1-e)p)] \\ &= (p-\mu)e(1-e) \\ &> 0 \end{aligned}$$

where the last inequality follows because $\mu < p$ and $e < 1$. Since the proof for the D-equilibrium part is symmetric, this completes the proof.

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