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Adjudicating Technical Cases

Jing-Yuan Chiou, Su-Hua Lee, and I-Ping Wang*

To properly adjudicate a case characterized by technical details, a judge needs to spend considerable effort and resources to understand the relevant knowledge and evidence. Incorporating this element into a litigation model, private incentives in evidence collection are shown to be increasing in a judge's effort to process information. Diverting limited judicial resources to collect information, then, may generate multiple equilibria with different resource allocations. An equilibrium with more judicial resources devoted to information collection is accompanied with fewer resources for understanding, and thus lower private search effort. Unless the search capacity of the court is sufficiently high, public search will reduce the overall quality of judicial decision making. The model is also extended to consider whether a judge should disclose his "inner conviction" (心證), captured as the *interim* belief, before litigants present their evidence to the court. Disclosure is socially optimal under a general sufficient condition, namely, the first-order effect of the belief on private search dominates the second-order effect.

Keywords: belief disclosure, bayesian persuasion, judicial decision making
JEL classification: D83, K41, O34

*Department of Economics, National Taipei University, Department of Law, National Taiwan University, and Department of Law, National Taipei University. Corresponding author: Jing-Yuan Chiou, email: jychioua@gmail.com We are grateful to two anonymous referees and seminar participants at National Central University for very helpful comments, and the Faculty Group Research Funding Sponsorship of National Taipei University for financial support. All errors are ours.

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1 Introduction

In 2008, Taiwan established the Intellectual Property Court (智慧財產法院) to hear all IP-related cases.[1] Similar to the Court of Appeals for the Federal Circuit (CAFC) in the United States, the Intellectual Property High Court (IPHC) in Japan, and specialized courts in other countries, the creation of a centralized litigation venue in Taiwan is a policy response to challenges in modern economy. Rapid industrial evolutions, continuing technological progress, and growing complications of economic and social activities in our society imply that legal disputes in many areas, including patent law, often require specialized expertise to properly adjudicate. The legal system needs to deal with cases characterized by technical knowledge that may be absent in a judge's legal training.

The challenge we stress here is not only that the judge lacks information, or that litigants have incentives to manipulate information. Even with abundant authentic information, because of its technical nature, the mere presentation to the court might not guarantee a sound judgement. The judge would also need to spend considerable resources to digest and extract useful knowledge from presented materials.[2] In this paper, we regard the judicial decision making as a team work, consisting of evidence submission by litigants and information processing by the judge. Both activities consume resources, and neither is dispensable. This feature of "moral hazard in teams" (Holmstrom, 1982) is essential to our analysis.

To our best knowledge, the literature in law and economics has mainly concerned with the incentive and distortion in evidence generation. It typically assumes that the judge can understand the content of submitted materials at no cost.[3] The more recent work of Yee (2008) examines a situation where the judge can successfully verify evidence with an exogenous proba-

[1] For a general introduction, see the homepage of the court: http://ipc.judicial.gov.tw/ipr_english/ (visited on 06/06/2020).

[2] In the United States, after the decision of the Supreme Court in *Daubert vs. Merrell Dow Pharmaceuticals* (509 U.S. 579, 1993), the judge is required to screen scientific evidence and ensure that scientific testimony as well as evidence admitted in court is relevant and reliable. A substantial literature in the legal profession is devoted to this issue; see, for example, Damle (2005), Note (1997), and Peterson and Conley (2001), and Oldfather (2012).

[3] Classical contributions include Milgrom and Roberts (1986), Shin (1994, 1998), and Froeb and Kobayashi (1996, 2001). Also see Sanchirico (2012) and Sobel (2013) for literature reviews.

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bility, and obtains that both the qualities of private parties and the judge determine the performance of the judicial system. This paper shares the same basic insight as Yee (2008), but also exhibits important differences.

In Yee (2008), the quality of evidence possessed by litigants and, as stated above, the judge's ability to process information are both exogenously determined. By contrast, information search and processing are costly decisions in our model: private parties incur costs to collect, and the judge spends resources to understand information. Different modeling approaches reflect different focus of the two studies. Yee (2008) emphasizes strategic evidence submission by litigants, while we consider the incentive to collect evidence in the first place.[4] We also extend the analysis to the allocation of judicial resources, where the judge can divert resources to collect information, and the disclosure of the judge's belief. These two design aspects of the judicial system are not addressed by Yee (2008); our analysis thus complements Yee (2008).

We construct a litigation model that incorporates the communication element of Dewatripont and Tirole (2005) into the advocacy model of Dewatripont and Tirole (1999). Private parties exert costly efforts to collect and submit information in their favor to the court (the element of advocacy). The judge has at his disposal a fixed amount of resources that could be spent on processing and extracting useful information (the element of communication). More resources spent on information processing increase the probability that the judge will understand the evidence and make an informed decision. Together, private parties and the judge contribute to improve the judicial decision making.

By the nature of communication, if the judge makes no effort to process information, then private parties have no incentives to collect information. More resources incurred by the judge encourage private information search.

[4] In Yee (2008), for example, if a private party does not hold any relevant information (good evidence), submitting "bad" evidence that bears no information value is part of the equilibrium strategy. By contrast, irrelevant information plays no role in our model. Our starting point is that all information, good (relevant) or bad (irrelevant), needs to be processed to have any impact. The judge may make mistakes and wrongly interpret some information, or inadequately apply technical knowledge to the current case. But for a piece of irrelevant information that can be cheaply produced by private parties, either it is ignored because the judge does not read it, or it could easily be identified as irrelevant after the judge spent time and efforts to acquire sufficient knowledge of the technology field. Hence, we do not consider irrelevant information.

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In the basic model, there is a unique equilibrium of the litigation game: The judge spend all available resources to understand the materials, and the litigants set the search efforts accordingly.

We then use the equilibrium characterization to discuss two issues. First, we revisit the debate of the adversarial *vs.* inquisitorial system (see Froeb and Kobayashi (2012) for a literature review), and consider the allocation of judicial resources between information collection and processing.

In the presence of the resource constraint, if the judge spends more resources on information collection, fewer resources are available for processing information, which leads to a smaller likelihood of an informed decision. Private search incentives diminish. That is, public search crowds out private search. A more subtle point is that, different from the basic model, there may be multiple equilibria involving different allocations of judicial resources. An equilibrium with more judicial resources devoting to evidence collection is accompanied by fewer private search efforts and lower likelihood of an informed decision. If the search capacity of the court is not good enough, the equilibrium with more public search entails a lower quality of judicial decision making, namely, a lower probability of an informed decision and higher error rates in an informed decision. In this case, the judge may want to commit to a pure adversarial system.

Second, in addition to evidence submitted by litigants, the judge may also "do some homework," and prepare for the case by reading relevant materials or consulting experts or friends. By doing so, the judge may acquire the "inner conviction" (心證) that is different from the prior belief, before hearing arguments from the two parties. This inner conviction, captured in the model as the *interim* belief, may affect the way the judge interprets the evidence. An important question, then, is whether the judge should disclose such *interim* beliefs. The current law does not mandate disclosure, and we use our model to provide some preliminary discussion.[5]

In the standard decision theory, information is beneficial typically because it allows the decision maker to adjust the course of action. In our context, the *interim* belief, had it been known, does affect a litigant's search

[5]Article 8, section 2 of Intellectual Property Case Adjudication Act states: "*The Presiding Judge or Commissioned Judge shall direct the parties to issues concerning the legal relations of the disputed matters, and shall, whenever appropriate, provide his legal opinions and disclose conviction.*" The full text is available at https://law.judicial.gov.tw/LAWENG/FLAW/dat02.aspx?lsid=FL042720 (visited on 06/06/2020).

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decision. Knowing that the judge is more (less) likely to be swayed by his evidence, a litigant is more (less, respectively) willing to collect information. It is less clear, however, that disclosure also improves social welfare (which is a benevolent judge's objective). First, the two parties will respond to the same disclosure in opposite ways. Disclosing that the judge is "more friendly" to the plaintiff relative to the *ex ante* belief will raise the plaintiff's while decrease the defendant's search efforts. And second, given that *interim* beliefs are generated via the Bayesian updating process, it must be the case that sometimes the *interim* belief moves in favor of the plaintiff, and other times in favor of the defendant. It is not obvious that, *on average*, disclosure would provide a net social benefit.

In our model, litigants' adjustments of search efforts to the disclosure are socially beneficial if they coincide with the judicial objective of "seeking the truth:" A party should be encouraged to exert higher efforts if he is more likely to be right, so that the judge is more likely to side with him. We formalize this property, which relates to the idea of convex ordering (Ganuza and Penalva, 2010), and obtain a general sufficient condition: Disclosure is socially optimal if the first-order effect of belief on both litigants' search efforts dominates the second-order effect. This condition holds, for instance, with quadratic search costs.

To proceed, we introduce the model in section 2. We first consider the judicial decision rule as well as social value of information in section 3, and then analyze the litigation game in section 4. We then discuss the judicial resource allocation in section 5, and the disclosure of *interim* beliefs in section 6. In section 7, we offer some concluding remarks.

2 Model

Two parties, a plaintiff and a defendant, bring a legal dispute before a judge. Both parties incur costs to collect and submit relevant materials to the judge, who, after spending resources to process information at hand, issues a decision. For simplicity, the judge makes a binary decision, namely, a ruling for the plaintiff or for the defendant, and there is no appeal.[6] All players, including the judge, are risk neutral.

Winning the case gives party i a benefit $b_i > 0$, and losing generates a

[6]Therefore, we drop the "default option," i.e., no party wins, in Dewatripont and Tirole (1999).

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loss $l_i > 0$, where $i = P$ indicates the plaintiff and $i = D$ the defendant. Given a winning probability $x \in [0, 1]$ for the plaintiff, the expected payoff is

$$x \cdot b_P + (1 - x)(-l_P) = -l_P + x \cdot (b_P + l_P) = -l_P + x \cdot S_P \quad (1)$$

for the plaintiff, and

$$x \cdot (-l_D) + (1 - x)b_D = b_D - x \cdot (b_D + l_D) = b_D - x \cdot S_D \quad (2)$$

for the defendant, where $S_i \equiv b_i + l_i > 0$ denotes the stake for party $i \in \{P, D\}$.

While private parties care about winning,[7] the judge is concerned with the merit of the case (i.e., which party is supported by the facts and legal arguments) as well as the social consequence of the judgement (i.e., the precedential effect). Formally, there are two possible states of nature, $\theta \in \{P, D\}$. In the state of $\theta = P$, the correct decision is to rule for the plaintiff, and in $\theta = D$, the judge should rule for the defendant. Given the true state $\theta \in \{P, D\}$, the social welfare (which is also the judge's objective) of a correct decision, $\bar{w}_\theta$, exceeds that of the wrong decision, $\underline{w}_\theta$. Define $\triangle_\theta \equiv \bar{w}_\theta - \underline{w}_\theta > 0$ as the welfare improvement of making the correct decision at state $\theta \in \{P, D\}$.

Neither the judge nor private parties observe the true state of nature. All parties have the same *ex ante* belief that the true state is $\theta = P$ with probability $\alpha^0 \in (0, 1)$. Before making a decision, the judge may learn some information about the true state. Consider a signal $\hat{\theta}$ that may take four possible values, $\hat{\theta} \in \{\theta_P^+, \theta_P, \theta_D, \theta_D^+\}$, and has the following conditional probability distribution:

$$\text{when } \theta = P, \begin{cases} \Pr\left(\hat{\theta} = \theta_P^+ | \theta = P\right) = e_P, \\ \Pr\left(\hat{\theta} = \theta_P | \theta = P\right) = (1 - e_P)(1 - \varepsilon_P), \\ \Pr\left(\hat{\theta} = \theta_D | \theta = P\right) = (1 - e_P)\varepsilon_P, \\ \Pr\left(\hat{\theta} = \theta_D^+ | \theta = P\right) = 0; \end{cases} \quad (3)$$

[7] From expression (1) and (2), higher x benefits the plaintiff and harms the defendant.

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and

$$\text{when } \theta = D, \begin{cases} \Pr\left(\hat{\theta} = \theta_P^+ | \theta = D\right) = 0, \\ \Pr\left(\hat{\theta} = \theta_P | \theta = D\right) = (1 - e_D)\,\varepsilon_D, \\ \Pr\left(\hat{\theta} = \theta_D | \theta = D\right) = (1 - e_D)\,(1 - \varepsilon_D), \\ \Pr\left(\hat{\theta} = \theta_D^+ | \theta = D\right) = e_D. \end{cases} \tag{4}$$

The realization of θ_P^+, if observable, perfectly informs the true state $\theta = P$, for it cannot occur in the other state $\theta = D$, i.e., $\Pr(\theta_P^+ | \theta = D) = 0$; similarly, θ_D^+ unmistakeably identifies the true state $\theta = D$, for $\Pr(\theta_D^+ | \theta = P) = 0$. The other two signal values θ_P and θ_D could be realized in both states, thus only provide imperfect information. Their precision depends on two sets of variables. Higher e_p and e_D, or lower ε_P and ε_D, reduce the likelihood that θ_i is realized in the wrong state $j \neq i$, i and $j \in \{P, D\}$, and make it more informative.

The set of variables $(\varepsilon_P, \varepsilon_D)$ are parameters of the model. They measure the intrinsic, or "pre-existing" error rates of the signal value θ_P and θ_D. These errors could be alleviated by the litigants' choices, (e_P, e_D), referred to as their search efforts. At a cost $c_i(e_i)$, the party $i \in \{P, D\}$ chooses unobservable efforts e_i to search for information and decrease the likelihood of realizing the signal value θ_j, $j \in \{P, D\}$ and $j \neq i$. The cost function c_i is strictly increasing and convex, and satisfies $c_i(0) = c_i'(0) = 0$, $c_i'(e) > 0$ for $e \in (0, 1)$, $c_i'(1) = \infty$, and $c_i''(e) > 0$ for $e \in [0, 1]$, $i \in \{P, D\}$.

While private parties can spend any costs that are justifiable by the benefits (i.e., c_P and c_D are not bounded above), the court, as a branch of the government, is often operated under tight and inflexible resource constraints. To capture the idea, we assume that the judge has at his disposal a fixed amount of resources R devoting to the case. Spending $r \in [0, R]$ on processing information generates a probability $I(r) \in [0, 1]$ that the judge learns partial information about the signal, namely, whether the realized value of $\hat{\theta}$ falls in the partition $\Theta_P \equiv \{\theta_P^+, \theta_P\}$ or partition $\Theta_D \equiv \{\theta_D, \theta_D^+\}$. With probability $1 - I(r)$, the judge does not learn anything and maintains the *ex ante* belief α^0. The function $I(r)$ satisfies $I(0) = 0$, $I(R) \leq 1$, and $I'(r) > 0$ as well as $I''(r) < 0$ for all $r \in [0, R]$. (In section 5, the judge can also use resources to collect information. The relevant setting will be introduced there.)

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The whole setting, including the following timing of the game, is common knowledge to all players:

- Private parties simultaneously choose (unobservable) e_P and e_D, which determine the probability distribution of the signal; and then
- the judge chooses resources $r \in [0, R]$, forms the belief, and makes the decision.

Note that, in our model, litigants do not directly discover signal θ_i or θ_i^+, $i \in \{P, D\}$. Instead, they indirectly influence the judge's opinion formation via informational inputs to be consumed by the judge. In other words, we take the Bayesian persuasion approach (Gentzkow and Kamenica, 2017; Kamenica and Gentzkow, 2011):[8] senders (the litigants here) can affect the information structure, but cannot directly manipulate (i.e, suppress or fabricate) the information observed by the receiver (the judge). This approach allows us to abstract from strategic information submission (Yee, 2008), and focus on search incentives. It also captures important features of patent disputes.

In addition to the technical nature, patent disputes may involve issues that entail elements of subject evaluations, such as the non-obviousness criterion of patentability.[9] Instead of finding the "killer evidence," the battle in the court may be more about who can make convincing arguments to sway the judge. To capture this aspect, we have in mind a situation where information or evidence comes with different strength. Some (θ_P^+ and θ_D^+) are more persuasive than the other (θ_P and θ_D). To fix the idea, we refer to the former as ironclad proof, and the latter as circumstantial evidence. Technological complexities of the case and insufficient technical training raise obstacles for the judge to tell the former from the latter. If learning anything, the judge at most learns whether the evidence is pro-plaintiff ($\hat{\theta} \in \Theta_P$) or pro-defendant ($\hat{\theta} \in \Theta_D$). What litigants can do is to raise the probability of

[8]The interaction between a prosecutor and a judge is also the leading example in Kamenica and Gentzkow (2011).

[9]To quote Judge Learned Hand: "*[T]here will remain cases when we can only fall back upon such good sense as we may have · · · There comes a point when the question must be resolved by a subjective opinion as to what seems an easy step and what does not. We must try to correct our standard by such objective references as we can, but in the end the judgment will appear, and no doubt be, to a large extent personal, and in that sense arbitrary.*" *Kirsch Mfg. Co. v. Gould Mersereau Co.*, 6 F.2d 793, 794 (2d Cir. 1925).

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including ironclad evidence in the submitted information, so that the judge is more likely to observe evidence in their favor.

The judge's inability of further refining the partition Θ_P and Θ_D is also consistent with our emphasis of judicial decision-making as a team work. A sound judgement requires the judge comprehend, *and* litigants provide high quality information. Even if the judge always understands evidence in hand (i.e., $I = 1$), there is still the possibility of judicial mistakes, unless litigants have exerted maximal efforts ($e_P = e_D = 1$) and submitted materials containing only ironclad evidence.[10]

Similarly, probabilistic learning implies that it is not enough for the litigants to bring evidence, precedents, expert testimonies, or legal arguments to the judge's attention (Dewatripont and Tirole, 2005). Equally important is the judge's appreciation of the materials. One might argue that a judge should be well-trained to easily decipher facts and law relevant to the case. The right question, we believe, is one of degree: To what extent can a judge rely on prior experiences and general legal training to make a sound decision, without extra efforts to process case specific materials? In well-established and stable areas such as tort law and property law, cases might be more or less "standardized" and the legal implications of evidence readily understood. Patent law, however, functions in a highly volatile and rapidly changing environment; even a seasoned judge would need to spend considerable energy to keep up with the technical details of each dispute. We construct this model to study such technical cases where a proper adjudication requires non-negligible case-specific efforts from the judge.

3 The judicial decision rule

We first consider the judge's optimal decision rule and the social value of information. Holding a belief that the true state is $\theta = P$ with probability α (not necessarily the initial belief), the expected welfare of ruling for the plaintiff is $W_P \equiv \alpha \bar{w}_P + (1-\alpha)\underline{w}_D$: with probability α, a correct decision leads to social welfare $\bar{w}_P$; and with probability $1-\alpha$, this judicial mistake generates welfare $\underline{w}_D$. Similarly, the expected welfare of a judgement for the defendant is $W_D \equiv \alpha \underline{w}_P + (1-\alpha)\bar{w}_D$.

[10] This information structure also simplifies the analysis. Together with Assumption 1, to be introduced in section 3, the judge's optimal decision would be independent of private efforts e_P and e_D (see section 3).

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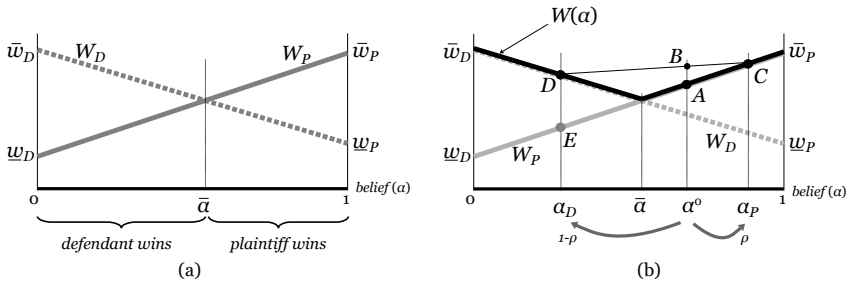


Figure 1: The judicial decision rule

Comparing W_P with W_D, the judge will optimally rule for the plaintiff when $W_P > W_D$, or, equivalently, when $\alpha > [(\bar{w}_D - \underline{w}_D)/(\bar{w}_P - \underline{w}_P + \bar{w}_D - \underline{w}_D)] = [\triangle_D/(\triangle_P + \triangle_D)] \equiv \bar{\alpha} \in (0, 1)$; and rule for the defendant otherwise. Figure 1(a) illustrates this cut-off rule: The grey solid line and dashed line represent W_P and W_D, respectively.[11] The two lines intersect at the threshold $\bar{\alpha}$, which depends on the relative importance of correct decisions. For instance, the term $\triangle_P$ measures the social cost of wronging the plaintiff. As this cost grows, holding $\triangle_D$ constant, the threshold $\bar{\alpha}$ decreases, and the judge should decide for the plaintiff over a broader range of beliefs.[12]

Given belief α, the optimal welfare,

$$W(\alpha) \equiv \max\{W_P(\alpha), W_D(\alpha)\}, \tag{5}$$

depicted as the black line in Figure 1(b), is the upper envelope of the two grey lines in Figure 1(a). That is, when $\alpha > \bar{\alpha}$, the judge rules for the

[11] Upon indifference, we let the judge rule for the defendant. In Figure 1 and 2, we consider the case of $\bar{w}_P > \underline{w}_D$ and $\bar{w}_D > \underline{w}_P$. The slope of the grey solid line is positive and that of the grey dashed line is negative. These assumptions, however, are immaterial to our analysis. Also see footnote 14.

[12] This decision rule is consistent with the evidentiary rule in different fields of law. In civil law, the prevailing standard of "preponderance of evidence" is typically interpreted as the requirement that the plaintiff win the case if the evidence suggests a probability of strictly higher than 50% in favor of the plaintiff, i.e., $\bar{\alpha} = 0.5$ (Cooter and Ulen, 1997), reflecting the view that, in these cases, social costs of wronging either party are roughly the same. The "clear and convincing evidence" that is used in the intellectual property rights dispute typically requires $\bar{\alpha} = 0.7$; and the most stringent standard of "beyond reasonable doubt," mostly used in criminal law, is associated with $\bar{\alpha} = 0.9$.

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plaintiff and obtains an expected payoff $W_P(\alpha)$, and when $\alpha \leq \bar{\alpha}$, the defendant wins and the expected welfare is $W_D(\alpha)$. Note that $W(\alpha)$ is a convex function of α.

If the judge fails to understand the evidence, the expected welfare of making a default decision according to the *ex ante* belief α^0 is $W^0 \equiv W(\alpha^0) = \max\{W_P(\alpha^0), W_D(\alpha^0)\}$, which is represented by point A in Figure 1(b). (The figure considers the case of $\alpha^0 > \bar{\alpha}$, with $W^0 = W_P(\alpha^0)$.)

Suppose that the judge learns something. With probability

$$\rho \equiv \Pr\left(\hat{\theta} \in \Theta_P\right) = \alpha^0 \left[1 - (1 - e_P)\,\varepsilon_P\right] + \left(1 - \alpha^0\right)(1 - e_D)\,\varepsilon_D, \quad (6)$$

the judge observes the pro-plaintiff evidence, i.e., the signal falls in the set Θ_P, and changes the belief to

$$\alpha_P \equiv \Pr\left(\theta = P | \hat{\theta} \in \Theta_P\right) = \alpha^0 \left[1 - (1 - e_P)\,\varepsilon_P\right] / \rho; \quad (7)$$

and with probability $1 - \rho$, the judge learns the pro-defendant evidence (i.e., $\hat{\theta} \in \Theta_D$), and updates the belief to

$$\alpha_D \equiv \Pr\left(\theta = P | \hat{\theta} \in \Theta_D\right) = \alpha^0 (1 - e_P)\,\varepsilon_P / (1 - \rho). \quad (8)$$

The belief α_P is increasing, while α_D decreasing in e_P and e_D.

To simplify the analysis, we maintain the following assumption throughout the paper:[13]

Assumption 1. $[\alpha^0(1-\varepsilon_P)/\alpha^0(1-\varepsilon_P)+(1-\alpha^0)\varepsilon_D] > \bar{\alpha} > [\alpha^0\varepsilon_P/\alpha^0\varepsilon_P + (1-\alpha^0)(1-\varepsilon_D)]$.

This assumption ensures that the error rates of circumstantial evidence, ε_P and ε_D, are sufficiently small such that $\alpha_P > \bar{\alpha} > \alpha_D$ even when $e_P = e_D = 0$, and so the inequality holds for all e_P and e_D. The judge will optimally rule for party i after observing Θ_i, $i \in \{P, D\}$, regardless of the level of private search efforts. This assumption precludes the case where, despite private efforts, the judge is not swayed by the evidence and sticks to the default decision even after learning Θ_P or Θ_D. We will provide more discussion about this case in Remark 1 of section 4.

[13] Assumption 1 requires sufficiently small ε_P and ε_D. It demands more than an informative signal of θ_P and θ_D, which requires only $\varepsilon_P + \varepsilon_D < 1$.

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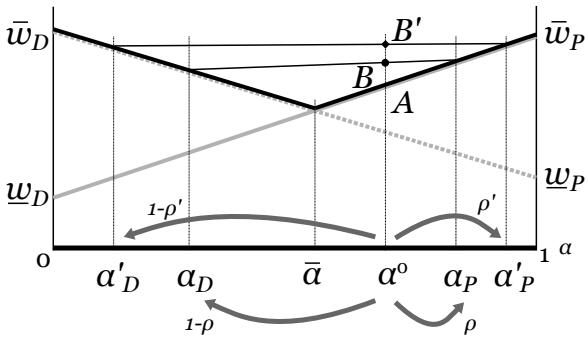


Figure 2: Value of information

Given Assumption 1, learning the information $\hat{\theta} \in \Theta_i$, $i \in \{P, D\}$, and making the informed decision generates expected welfare

$$W^I \equiv \rho W(\alpha_P) + (1-\rho) W(\alpha_D) = \rho W_P(\alpha_P) + (1-\rho) W_D(\alpha_D), \quad (9)$$

which corresponds to point B in Figure 1(b). With probability ρ, the judge observes the pro-plaintiff evidence Θ_P, updates the belief to α_P, rules for the plaintiff, and obtains welfare $W_P(\alpha_P)$. With probability $1-\rho$, an observation of the pro-defendant evidence $\hat{\theta} \in \Theta_D$ propels an updated belief α_D and a ruling for the defendant, leading to welfare $W_D(\alpha_D)$. "On average," Bayes' rule requires that $\rho\alpha_P + (1-\rho)\alpha_D = \alpha^0$, and so point A and B locate on the same vertical line in Figure 1(b).

The convexity of $W(\alpha)$ ensures welfare improvement by an informed decision; point B is higher than point A in Figure 1(b). In addition, more dispersion of the *ex post* belief α_P and α_D further increases welfare. Consider two sets of updated beliefs (α_P, α_D) and (α'_P, α'_D) in Figure 2. The latter are more disperse ($\alpha'_D < \alpha_D < \alpha_P < \alpha'_P$), and generate a higher expected payoff than the former, i.e., point B' is higher than point B.[14] In our model, higher e_i or lower ε_i, $i \in \{P, D\}$, both increase the dispersion of *ex post* beliefs and raise welfare.

To decipher the social value of information, we construct Table 1, which lists the true state of nature ($\theta \in \{P, D\}$), the signal ($\hat{\theta}$) and its conditional

[14] These properties correspond to those of "convex ordering" (Ganuza and Penalva, 2010), and do not dependent on whether $\bar{w}_P \gtrless \underline{w}_D$ or $\underline{w}_P \gtrless \bar{w}_D$, namely, the slope of W_P and W_D.

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Table 1: Information and the winning party

true state	signal ($\hat{\theta}$)	informed decision	default decision	
			$\alpha^0 > \bar{\alpha}$	$\alpha^0 \leq \bar{\alpha}$
$\theta = P$	$\theta_P^+ : e_P$	plaintiff	plaintiff	**defendant**
	$\theta_P : (1-e_P)(1-\varepsilon_P)$	plaintiff	plaintiff	**defendant**
	$\theta_D : (1-e_P)\varepsilon_P$	defendant	**plaintiff**	defendant
	$\theta_D^+ : 0$	—	—	—
$\theta = D$	$\theta_P^+ : 0$	—	—	—
	$\theta_P : (1-e_D)\varepsilon_D$	plaintiff	plaintiff	**defendant**
	$\theta_D : (1-e_D)(1-\varepsilon_D)$	defendant	**plaintiff**	defendant
	$\theta_D^+ : e_D$	defendant	**plaintiff**	defendant

probability (i.e., expression (3) and (4)), and the winning party in the default as well as informed decision corresponding to the realization of the signal value. We also use the bold font to highlight those default decisions that are different from the informed decision.

When the default decision is to rule for the plaintiff (i.e., when $\alpha^0 > \bar{\alpha}$), an informed decision may deviate in two ways. First, learning the pro-defendant evidence Θ_D wrongly changes the judgement to a ruling for the defendant if the true state is $\theta = P$. This happens when the signal value is $\hat{\theta} = \theta_D$, occurring with conditional probability $(1-e_P)\varepsilon_P$ and inflicting a welfare loss $\triangle_P$. But if the judge correctly learns the pro-defendant evidence in the true state $\theta = D$, which occurs with conditional probability $1-(1-e_D)\varepsilon_D$, welfare improves by $\triangle_D$. Overall, an informed decision brings a net benefit

$$W^I - W^0 \equiv v_P = -\alpha^0 (1-e_P)\, \varepsilon_P \triangle_P + \left(1-\alpha^0\right)\left[1-(1-e_D)\, \varepsilon_D\right] \triangle_D. \tag{10}$$

Similarly, when the default decision is to rule for the defendant (i.e., when $\alpha^0 \leq \bar{\alpha}$), learning information improves welfare by

$$W^I - W^0 \equiv v_D = \alpha^0 \left[1-(1-e_P)\, \varepsilon_P\right] \triangle_P - \left(1-\alpha^0\right)(1-e_D)\, \varepsilon_D \triangle_D. \tag{11}$$

In this case, learning the pro-plaintiff evidence and changing the decision to rule for the plaintiff is correct when the true state is $\theta = P$, which

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corresponds to the first term in v_D, but incorrect when $\theta = D$, which generates the second term in v_D.

By Assumption 1, both v_P and v_D are strictly positive for all e_P and e_D. To see this, we decompose v_P and v_D into two parts, those affected by private efforts and those not affected: $v_i = \underline{v}_i + \triangle v(e_P, e_D)$, $i \in \{P, D\}$, where $\triangle v(e_P, e_D) \equiv \alpha^0 \varepsilon_P \triangle_P e_P + (1-\alpha^0)\varepsilon_D \triangle_D e_D$, and $\underline{v}_i \equiv -\alpha^0 \varepsilon_P \triangle_P + (1-\alpha^0)(1-\varepsilon_D)\triangle_D$ for $i = P$ and $\alpha^0(1-\varepsilon_P)\triangle_P - (1-\alpha^0)\varepsilon_D \triangle_D$ for $i = D$, respectively. Private efforts only affect $\triangle v$, but not $\underline{v}_i$, $i \in \{P, D\}$. Since $\triangle v$ is strictly increasing in e_P and e_D, v_i is strictly positive as long as $\underline{v}_i$ is strictly positive, $i \in \{P, D\}$, which is indeed what Assumption 1 guarantees.

Intuitively, learned information could always be discarded if it does not help the decision making; the value of information cannot be negative in our model. By Assumption 1, the judge will take into consideration the observation of evidence Θ_P and Θ_D. In Figure 1(b), where the default decision is to rule for the plaintiff (for $\alpha^0 > \bar{\alpha}$) and the associated welfare W^0 is represented by point A, learning the pro-plaintiff evidence Θ_P will not change the ruling, with welfare represented by point C in the figure. If the judge observes the pro-defendant evidence Θ_D, by Assumption 1 the optimal decision becomes to rule for the defendant, with welfare represented by point D. As stated above, the expected welfare W^I corresponds to point B. Had Assumption 1 failed and the judge maintained the ruling for the plaintiff, welfare would then be represented by point E in Figure 1(b). On average, the welfare of always ruling for the plaintiff is still indicated by point A. Assumption 1, by ensuring that the judge's optimal decision is sensitive to evidence, generates a strictly positive value of information v_P, which is represented by the vertical distance between point B and A in the figure. Similarly, for the case of $\alpha^0 \leq \bar{\alpha}$, Assumption 1 also ensures that $v_D > 0$.

Since v_P and v_D share the same $\triangle v$, the marginal social benefits of private efforts do not depend on the default decision:

$$\frac{\partial v_i}{\partial e_P} = \alpha^0 \varepsilon_P \triangle_P > 0 \quad \text{and} \quad \frac{\partial v_i}{\partial e_D} = (1-\alpha^0)\varepsilon_D \triangle_D > 0, \quad i \in \{P, D\}. \tag{12}$$

These marginal benefits are proportional to (i) the *ex ante* probability that the party will prevail (i.e., α^0 for the plaintiff and $1-\alpha^0$ for the defendant), for ironclad evidence can only occur in the corresponding true state (θ_P^+ in the state P and θ_D^+ the state D); (ii) the error rate of less informative

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signals (ε_P and ε_D), for the more likely that circumstantial evidence may lead to mistakes, the more useful is ironclad evidence; and (iii) the social cost of wrong decisions ($\triangle_P$ and $\triangle_D$), for avoiding these costs is the reason of making an informed decision in the first place. We summarize the discussion in Lemma 1.

Lemma 1. Suppose that $\alpha^0 \in (0, 1)$ and Assumption 1 holds. For all $(e_P, e_D) \in [0, 1]^2$: (i) α_P is increasing while α_D is decreasing in e_P and e_D; (ii) $\alpha_P > \bar{\alpha} > \alpha_D$; and (iii) $v_i > 0$ and is increasing in e_P and e_D, $i \in \{P, D\}$.

Proof. By $\partial\alpha_P/\partial e_P = [\alpha^0(1-\alpha^0)(1-e_D)\varepsilon_D\varepsilon_P]/(\rho^2) \geq 0$, $\partial\alpha_P/\partial e_D = \{\alpha^0(1-\alpha^0)[1-(1-e_P)\varepsilon_P]\varepsilon_D\}/(\rho^2) > 0$, $\partial\alpha_D/\partial e_P = \{-\alpha^0(1-\alpha^0)[1-(1-e_D)\varepsilon_D]\varepsilon_P\}/[(1-\rho)^2] < 0$, and $\partial\alpha_D/\partial e_D = -[\alpha^0(1-\alpha^0)(1-e_P)\varepsilon_P\varepsilon_D]/[(1-\rho)^2] \leq 0$, property (i) holds.

For property (ii), when $e_P = e_D = 0$, $\alpha_P = \{\alpha^0(1-\varepsilon_P)/[\alpha^0(1-\varepsilon_P) + (1-\alpha^0)\varepsilon_D]\}$ and $\alpha_D = \{\alpha^0\varepsilon_P/[\alpha^0\varepsilon_P + (1-\alpha^0)(1-\varepsilon_D)]\}$. By Assumption 1, $\alpha_P > \bar{\alpha} > \alpha_D$ when $e_P = e_D = 0$. Together with property (i), $\alpha_P > \bar{\alpha} > \alpha_D$ for all e_P and $e_D \in [0, 1]$.

For property (iii), an informed decision generates expected welfare

$$W^I = \alpha^0\bar{w}_P + \left(1-\alpha^0\right)\bar{w}_D - \alpha^0\left(1-e_P\right)\varepsilon_P\triangle_P - \left(1-\alpha^0\right)\left(1-e_D\right)\varepsilon_D\triangle_D, \tag{13}$$

which is strictly increasing in e_P and e_D. To show that $W^I > W^0$, or, equivalently, v_P and $v_D > 0$, it suffices to consider the case of $e_P = e_D = 0$.

When $\alpha^0 > \bar{\alpha}$ and so $W^0 = W_P(\alpha^0)$, the welfare difference is $W^I - W^0 = v_P = (1-\alpha^0)(1-\varepsilon_D)\triangle_D - \alpha^0\varepsilon_P\triangle_P$, which is strictly positive by the second part of Assumption 1, namely, $\bar{\alpha} > (\alpha^0\varepsilon_P)/[\alpha^0\varepsilon_P + (1-\alpha^0)(1-\varepsilon_D)]$. And when $\alpha^0 \leq \bar{\alpha}$, we have $W^0 = W_D(\alpha^0)$ and $W^I - W^0 = v_D = \alpha^0(1-\varepsilon_P)\triangle_P - (1-\alpha^0)\varepsilon_D\triangle_D$, which is also strictly positive by $[\alpha^0(1-\varepsilon_P)]/[\alpha^0(1-\varepsilon_P) + (1-\alpha^0)\varepsilon_D] > \bar{\alpha}$. ■

4 The litigation equilibrium

We now turn to the equilibrium of the litigation game. Because e_P and e_D are unobservable to other players, the judge's decision cannot depend on private search efforts. We are looking for a Nash equilibrium, and, for simplicity, consider only pure strategies.

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With probability $1 - I$, the judge fails to understand the evidence and makes the default decision based on the *ex ante* belief α^0. With probability I, the judge makes an informed decision and rules for party i after observing $\hat{\theta} \in \Theta_i$ $i \in \{P, D\}$. Depending on the default decision, the plaintiff seeks to maximize

$$\pi_P = \begin{cases} I\left[\rho b_P + (1-\rho)(-l_P)\right] + (1-I)b_P \\ \quad -c_P = b_P - I(1-\rho)S_P - c_P & \text{if} \quad \alpha^0 > \bar{\alpha}, \\ I\left[\rho b_P + (1-\rho)(-l_P)\right] + (1-I)\left(-l_P\right) \\ \quad -c_P = -l_P + I\rho S_P - c_P & \text{if} \quad \alpha^0 \leq \bar{\alpha}. \end{cases} \tag{14}$$

When $\alpha^0 > \bar{\alpha}$, the plaintiff wins and obtains b_P unless the judge observes the pro-defendant evidence $\hat{\theta} \in \Theta_D$, which occurs with probability $I(1-\rho)$ and reduces the plaintiff's payoff by S_P. And when $\alpha^0 \leq \bar{\alpha}$, the plaintiff loses unless the judge learns the pro-plaintiff evidence $\hat{\theta} \in \Theta_P$, occurring with probability $I\rho$ and increasing the payoff by S_P. Similarly, the defendant's expected payoff is

$$\pi_D = \begin{cases} -l_D + I(1-\rho)S_D - c_D & \text{if} \quad \alpha^0 > \bar{\alpha}, \\ b_D - I\rho S_D - c_D & \text{if} \quad \alpha^0 \leq \bar{\alpha}. \end{cases} \tag{15}$$

For both $\alpha^0 \gtrless \bar{\alpha}$, the plaintiff's optimal effort $\hat{e}_P \equiv \arg\max_{e_P} \pi_P$ is determined by the first-order condition[15]

$$FOC: \quad \frac{\partial \rho}{\partial e_P} I S_P = \alpha^0 \varepsilon_P I S_P = c_P'(\hat{e}_P), \tag{16}$$

and the defendant's optimal choice $\hat{e}_D \equiv \arg\max_{e_D} \pi_D$ by

$$FOC: \quad \frac{\partial \rho}{\partial e_D} I S_D = (1-\alpha^0)\varepsilon_D I S_D = c_D'(\hat{e}_D). \tag{17}$$

If $I = 0$, the judge always makes the default decision; litigants' efforts do not affect the outcome of the suit. The plaintiff wins for sure if $\alpha^0 > \bar{\alpha}$, and the defendant wins if $\alpha^0 \leq \bar{\alpha}$. No party has any incentive to exert any

[15] The second-order conditions hold because of strictly convex cost functions c_P and c_D. From the first-order condition, a marginal increase in e_P always brings a benefit $\alpha^0 \varepsilon_P I S_P$ to the plaintiff, and an increase in e_D a benefit $(1-\alpha^0)\varepsilon_D I S_D$ to the defendant. The two parties have no incentive to withhold information, in the sense of reducing the likelihood of ironclad evidence, $\Pr(\hat{\theta} = \theta_i^+ | \theta = i)$, $i \in \{P, D\}$.

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effort, $\hat{e}_P = \hat{e}_D = 0$. Only when $I > 0$ will a litigant conduct costly search to improve the quality of information, and a higher I raises $\hat{e}_P$ and $\hat{e}_D$. This is the "double moral hazard" nature of communication (Dewatripont and Tirole, 2005).

The judge, on the other hand, maximizes

$$I(r)W^I + [1 - I(r)]W^0 = W^0 + I(r)v_i, \quad \text{where} \begin{cases} i = P & \text{if} \quad \alpha^0 > \bar{\alpha}, \\ i = D & \text{if} \quad \alpha^0 \leq \bar{\alpha}, \end{cases} \tag{18}$$

subject to the budget constraint $0 \leq r \leq R$. Since v_P and $v_D > 0$ by Lemma 1, the judge will spend all resources in information processing, $r^* = R$. The litigation game admits a unique equilibrium, where the judge makes an informed decision with probability $I^* \equiv I(R)$ and litigants exert efforts $e_P^* \equiv \hat{e}_P(I^*)$ and $e_D^* \equiv \hat{e}_D(I^*)$.

Proposition 1. (The litigation equilibrium) There is a unique Nash equilibrium in pure strategy of the litigation game. The judge puts all resources into processing information and makes an informed decision with probability I^*, and litigants' equilibrium efforts e_P^* and e_D^* are determined by, respectively,

$$\alpha^0 \varepsilon_P S_P I^* = c_P'\left(e_P^*\right) \quad \text{and} \quad \left(1 - \alpha^0\right) \varepsilon_D S_D I^* = c_D'\left(e_D^*\right). \tag{19}$$

Remark 1. In section 3, we have shown that the default decision does not affect the social value of information. Here, it does not have any impact on $\hat{e}_P$ and $\hat{e}_D$, either. Compare the informed decision with default decision in Table 1. The plaintiff's efforts only affect the conditional distribution in the state of $\theta = P$. Higher e_P (i) reduces the error of learning the pro-defendant evidence when the default decision is to rule for the plaintiff, or (ii) increases the likelihood that the judge observes the pro-plaintiff evidence when the default decision is the rule for the defendant. Both cases change the plaintiff's payoff by S_P, with the former occurring with probability proportional to $\alpha^0(1 - e_P)\varepsilon_P$ and the latter $\alpha^0[1 - (1 - e_P)\varepsilon_P]$. Multiplied by the probability I of an informed decision, the marginal benefit of e_P is equal to $\alpha^0 \varepsilon_P I S_P$. Similar reasoning applies to the defendant's efforts e_D.[16] ■

[16]The effort e_D only appears in the conditional distribution of the state $\theta = D$. By

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Remark 2. By Assumption 1, the judge always responds to the observation of Θ_P or Θ_D. This assumption precludes an "unresponsive" case where the initial belief entirely determines the outcome of the litigation, even if the judge understands the evidence. For example, in the case of $\alpha^0 \geq \bar{\alpha}$, the failure of Assumption 1 may cause an insufficiently convincing Θ_D, such that its observation cannot persuade the judge to rule for the defendant. Since the plaintiff would always prevail, neither party have any incentives to collect information. There would be zero private effort in equilibrium. We impose Assumption 1 and preclude such cases.

This preclusion can be justified by a pre-trial settlement bargaining stage, and an arbitrarily small but strictly positive fixed cost of litigation. Suppose that, before going to the court, the two parties meet for settlement bargaining. If the negotiation fails, then the plaintiff decides whether to seek a full trial, which costs both parties a fixed cost. This fixed cost is different from the cost of collecting evidence c_P and c_D. It may be the cost of preparing the paper work and filing the litigation, administrative fees charged by the court, or the time and efforts to recruit the legal team. A strictly positive, however small, amount would suffice.

If the defendant would always win in equilibrium, then a small fee discourages the plaintiff from starting the litigation, and the defendant could just ignore the plaintiff's offer of settlement. And if the plaintiff would always win, then there is a credible threat of litigation, and the two parties would agree to settle in order to save the fixed cost. In both cases, there would be no trial.

When Assumption 1 holds, on the other hand, "asymmetric stake" (Rubin, 1977) may cause the settlement bargaining to break down, while the plaintiff has a credible threat of litigation. Suppose that the plaintiff brings the suit to reverse the status quo, which is the prevailing outcome when there is no litigation or when the court rules against the plaintiff. The joint payoff under settlement, then, is $b_D - l_P$. Without settlement, the plaintiff's

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increasing the probability of realizing θ_D^+, and so the chance that the judge observes the pro-defendant evidence Θ_D, higher e_D either helps (i) to reverse the default decision of ruling for the plaintiff (when $\alpha^0 > \bar{\alpha}$), which occurs with probability proportional to $(1 - \alpha^0)[1 - (1 - e_D)\varepsilon_D]$; or (ii) to prevent the judge from abandoning the default decision of ruling for the defendant (when $\alpha^0 \leq \bar{\alpha}$), which occurs with probability proportional to $(1 - \alpha^0)(1 - e_D)\varepsilon_D$. Together with the probability I, the marginal benefit of e_D for the defendant is $(1 - \alpha^0)\varepsilon_D I S_D$, independent of the default decision.

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expected payoff of going through the trial (π_P^*) is $b_P - I^*(1-\rho^*)S_P - c_P^*$ for $\alpha^0 > \bar{\alpha}$, and $-l_P + I^*\rho^* S_P - c_P^*$ for $\alpha^0 \leq \bar{\alpha}$, respectively, where I^*, ρ^*, and c_P^* are evaluated at the equilibrium level described in Proposition 1. Since the plaintiff optimally chooses a strictly positive equilibrium effort, $e_P^* > 0$, rather than zero effort (and so no search cost), by the revealed preference argument, $b_P - I^*(1-\rho^*)S_P - c_P^* > b_P - I^*(1-\check{\rho})S_P - 0 > -l_P$ for $\alpha^0 > \bar{\alpha}$, and $-l_P + I^*\rho^* S_P - c_P^* > -l_P + I^*\check{\rho} S_P - 0 > -l_P$ for $\alpha^0 \leq \bar{\alpha}$, where $\check{\rho}$ is the probability ρ in expression (6) evaluated at e_D^* and $e_P = 0$ (i.e., only the plaintiff deviates to zero effort). Therefore, the plaintiff is willing to pay a small fee to file the suit, i.e., there is a credible threat to sue.

The defendant's equilibrium payoff from the litigation is $\pi_D^* = -l_D + I^*(1-\rho^*)S_D - c_D^*$ for $\alpha^0 > \bar{\alpha}$, and $b_D - I^*\rho^* S_D - c_D^*$ for $\alpha^0 \leq \bar{\alpha}$. Summing up the two parties' equilibrium payoff, the joint surplus from litigation is $b_P - l_D + I^*(1-\rho^*)(S_D - S_P) - (c_P^* + c_D^*)$ for $\alpha^0 > \bar{\alpha}$, and $b_D - l_P + I^*\rho^*(S_P - S_D) - (c_P^* + c_D^*)$ for $\alpha^0 \leq \bar{\alpha}$. Litigation leads to higher joint surplus than settlement if (i) $c_P^* + c_D^* < [1 - I^*(1-\rho^*)](S_P - S_D)$ when $\alpha^0 > \bar{\alpha}$; and (ii) $c_P^* + c_D^* < I^*\rho^*(S_P - S_D)$ when $\alpha^0 \leq \bar{\alpha}$. When these conditions hold, there will be no settlement, and Proposition 1 still characterizes the extended game with the settlement stage. ■

5 Allocations of judicial resources

For the remaining of the paper, we use the basic model to address two issues: the allocation of judicial resources in this section, and the disclosure of *interim* beliefs in the next section.

Suppose that, besides information processing, the judge can also spend resources on information search. The resource allocation decision is made after private parties submit materials, but before the judge processes information. Evidence collection by the court is a feature of the inquisitorial system, while a judge in a pure adversarial system would refrain from doing so. The discussion here relates to the merit of the two systems.

Denote s as the amount of resources spent on information search. The judicial resource constraint now becomes $0 \leq r + s \leq R$, where r and $s \geq 0$. Spending r on processing information still generates a probability $I(r)$ of observing Θ_i, $i \in \{P, D\}$. Spending resources on collecting information, similar to litigants' efforts, raises the probability of realizing $\hat{\theta}_P^+$ and $\hat{\theta}_D^+$. We assume that, without sufficient prior knowledge about the case,

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the judge cannot conduct "targeted search," namely, collecting information that only favors one party. The idea is that the judge first gathers information, and then, together with submission by private parties, exerts efforts to understand all materials at hand. At the search stage, without knowing the content of information (which requires processing and understanding), the judge cannot collect information that only increases $\Pr(\hat{\theta} = \theta_P^+ | \theta = P)$ (favorable to the plaintiff) or $\Pr(\hat{\theta} = \theta_D^+ | \theta = D)$ (favorable to the defendant). Instead, the public efforts provide an equal boost to these probabilities.

Define $E_i \equiv e_i + (e_J/2)$, $i \in \{P, D\}$, where $e_J(s)$ is a function of s, the resources spent by the judge, and satisfies $e_J(0) = 0$, $e_J(R) < 1$, $e_J' > 0$, and $e_J'' < 0$. We replace e_i with E_i in the conditional probability distribution of the signal $\hat{\theta}$:

$$\text{when } \theta = P, \begin{cases} \Pr\left(\hat{\theta} = \theta_P^+ | \theta = P\right) = \min\{1, E_P\}, \\ \Pr\left(\hat{\theta} = \theta_P | \theta = P\right) = (1 - \min\{1, E_P\})(1 - \varepsilon_P), \\ \Pr\left(\hat{\theta} = \theta_D | \theta = P\right) = (1 - \min\{1, E_P\})\varepsilon_P, \\ \Pr\left(\hat{\theta} = \theta_D^+ | \theta = P\right) = 0; \end{cases} \tag{20}$$

and

$$\text{when } \theta = D, \begin{cases} \Pr\left(\hat{\theta} = \hat{\theta} = \theta_P^+ | \theta = D\right) = 0, \\ \Pr\left(\hat{\theta} = \theta_P | \theta = D\right) = (1 - \min\{1, E_D\})\varepsilon_D, \\ \Pr\left(\hat{\theta} = \theta_D | \theta = D\right) = (1 - \min\{1, E_D\})(1 - \varepsilon_D), \\ \Pr\left(\hat{\theta} = \theta_D^+ | \theta = D\right) = \min\{1, E_D\}. \end{cases} \tag{21}$$

The additive form $e_i + (e_J/2)$, $i \in \{P, D\}$, implies that information collection carried out by the court and litigants does not interfere with each other; there is neither synergy nor duplication in their search activities. This assumption of "fishing in different ponds" is a strong one, for they are looking for evidence, expert witness, and scientific and technical materials of the same case in the same jurisdiction. This case, nevertheless, provides a useful benchmark; it also gives evidence collection by the court some benefits of the doubt.

Since private efforts are unobservable, the judge's search decision s cannot depend on e_P and e_D. We are still looking for a Nash equilibrium (in pure strategy). The following lemma describes two simple, yet useful, fea-

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tures of an equilibrium.

Lemma 2. An equilibrium strategy $(e_P^{**}, e_D^{**}, r^{**}, s^{**})$ satisfies (i) $r^{**} + s^{**} = R$ and (ii) $E_i^{**} = e_i^{**} + (e_J^{**}/2) \leq 1$, where $e_J^{**} \equiv e_J(s^{**})$, $i \in \{P, D\}$.

Proof. For (i), suppose that, in equilibrium, $r^{**} + s^{**} < R$. By Lemma 1, v_P and $v_D > 0$; raising r and so I improves welfare.

For (ii), suppose that $e_i^{**} + (e_J^{**}/2) > 1$ for some $i \in \{P, D\}$. By assumption, $e_J(R) < 1$, we must have $e_i^{**} > 0$, i.e., party i will engage in costly search. But in this case, the probability $\Pr(\hat{\theta} = \theta_i^+ | \theta = i) = 1$. Party i can marginally reduce e_i to save the cost without reducing the winning probability. ■

The first property states that the judge's budget constraint must be binding in equilibrium; otherwise, any unused resources can be devoted to understanding evidence and raising the probability of an informed decision. Although the time sequence entails that the judge first collects, then reads and tries to understand information, a binding resource constraint implies a simultaneous determination of r and s. Once s is chosen, the rest goes to r, i.e., $r = R - s$.

By the second property, $E_i^{**} \leq 1$, the analysis can be confined to the case of $\min\{1, E_i\} = E_i$, $i \in \{P, D\}$. The social values of information, v_P and v_D, are evaluated at E_P and E_D in the expression (10) and (11), respectively. Since e_J exerts an equal impact on $\Pr(\theta_P^+ | \theta = P)$ and $\Pr(\theta_D^+ | \theta = D)$, its marginal social benefit, denoted by γ, is

$$\gamma \equiv \frac{\partial v_i}{\partial E_P}\frac{\partial E_P}{\partial e_J} + \frac{\partial v_i}{\partial E_D}\frac{\partial E_D}{\partial e_J} = \frac{1}{2}\left[\alpha^0 \varepsilon_P \triangle_P + \left(1 - \alpha^0\right)\varepsilon_D \triangle_D\right], \quad (22)$$

for both $\alpha^0 > \bar{\alpha}$ and $\alpha^0 \leq \bar{\alpha}$, and $i \in \{P, D\}$.[17]

An equilibrium is determined by the simultaneous satisfaction of the first-order condition of the three players, as stated in the following proposition.

[17] By $E_i = e_i + (e_J/2)$, e_J plays a similar role to e_i, $i \in \{P, D\}$, in the conditional distribution. We can then compute γ by finding the marginal social benefits of e_P and e_D, summing them up, and then dividing by two. In the expression (12), $\partial v_i/\partial e_P$ corresponds to the first term in γ, and $\partial v_i/\partial e_D$ the second term, $i \in \{P, D\}$.

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Proposition 2. (Resource allocation) Consider an equilibrium $(e_P^{**}, e_D^{**}, r^{**})$, and let $s^{**} = R - r^{**}$, $I^{**} = I(r^{**})$, and $E_i^{**} = e_i^{**} + (e_J^{**}/2)$, $i \in \{P, D\}$. The equilibrium strategy satisfies

$$\alpha^0 \varepsilon_P S_P I^{**} = c_P' \left(e_P^{**}\right), \tag{23}$$

$$\left(1 - \alpha^0\right) \varepsilon_D S_D I^{**} = c_D' \left(e_D^{**}\right), \tag{24}$$

and

$$I' \left(r^{**}\right) v_i \left(E_P^{**}, E_D^{**}\right) - I^{**} e_J' \left(s^{**}\right) \gamma \geq 0,$$
$$\text{where} \quad \begin{cases} i = P & \text{if} \quad \alpha^0 > \bar{\alpha}, \\ i = D & \text{if} \quad \alpha^0 \leq \bar{\alpha}; \end{cases} \tag{25}$$

condition (25) holds with a strict inequality only when $r^{**} = R$ and $s^{**} = 0$.

Proof. The second-order conditions for the private parties are $-c_i'' < 0$, $i \in \{P, D\}$. Given I^{**}, e_i^{**} is indeed party i's best response, $i \in \{P, D\}$. For the judge, the second-order condition is $I'' v_i - [I' e_J' - (I e_J'')/2]2\gamma < 0$, where $i \in \{P, D\}$, depending on the default decision. Given e_P^{**} and e_D^*, r^{**} is the best response of the judge. Condition (23) – (25) therefore characterize the equilibrium.

For the existence of an equilibrium, by the first-order condition (16) and (17), the best responses $\hat{e}_P$ and $\hat{e}_D$ are strictly increasing in I. Since the maximal possible value of I is I^*, the optimal private search efforts cannot exceed those specified in the equilibrium condition (19). All three players' choice variables are restricted to a compact and convex set: $e_i \in [0, e_i^*]$ for the private party $i \in \{P, D\}$, and $r \in [0, R]$ for the judge. By the continuity of c_i', $i \in \{P, D\}$, I', and e_J', Brouwer's fixed point theorem guarantees the existence of an equilibrium. ■

Private parties' first-order conditions are the same as before: setting $I = I^{**}$ in condition (16) and (17), we obtain condition (23) and (24), respectively. This is a result of the additive form $E_i = e_i + (e_J/2)$, $i \in \{P, D\}$, whereby public search does not affect the marginal productivity of private efforts. For the judge, the optimal allocation of judicial resources strikes a balance between two goals. Spending more on processing information (i.e., a higher r) raises the probability of an informed decision, which improves welfare by v_i, $i \in \{P, D\}$. But it also reduces the resources available for information collection, whose contribution to welfare is proportional to γ.

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In equilibrium, the judge always devotes some resource to process information, i.e., $r^{**} > 0$. Otherwise, there is no chance of an informed decision ($I^{**} = 0$), and the judge's first-order condition (25) is strictly positive, implying a strictly positive benefit of a marginal increase in r. By contrast, whether $s^{**} > 0$, i.e., whether the judge should spend any efforts to collect information, depends on the magnitude of $e'_J(0)$, which captures the capacity of public search. If $e'_J(0)$ is not large enough, we may have $r^{**} = R$ and condition (25) holds with strict inequality.[18]

Different from the previous case, multiple equilibria may arise here, with different allocations of judicial resources. An equilibrium with higher s^{**} must be accompanied with lower r^{**} and so lower probability of an informed decision, which in turn discourages private search. In other words, shifting judicial resources from information processing to collection substitutes private search with public search. If public search is not sufficiently productive, this substitution may reduce the overall quality of judicial decision making. There may be a lower probability of an informed decision (I smaller), and higher error rates (due to lower E_P and E_D) in an informed decision. We present an example of binary choices.

Example. (Binary choices) Consider the special case of binary choices. Slightly abusing the notation, let $\{0, e_i\}$ be the choice set of litigant i, who either chooses not to collect information (at zero cost), or incurs a cost $c_i > 0$ to raise the probability $\Pr(\hat{\theta} = \theta_i^+ | \theta = i)$ by $e_i > 0$, $i \in \{P, D\}$. The judge's choice set is $\{(\bar{I}, 0), (\underline{I}, e_J)\}$, with $\bar{I} > \underline{I} > 0$ and $e_J > 0$. Making an informed decision with a probability $\bar{I}$ requires resources $\bar{r}$, and a probability $\underline{I}$ requires $\underline{r}$. The resources spent on information collection (e_J) are $s > 0$, with $\bar{r} = \underline{r} + s = R$. The pair $(\bar{I}, 0)$ indicates that the judge puts all resources into information processing. By choosing the pair $(\underline{I}, e_J)$, some resources are shifted into information collection. We assume that $e_i + (e_J/2) < 1$, $i \in \{P, D\}$.

We describe conditions for both $(e_P^{**}, e_D^{**}, I^{**}, e_J^{**}) = (e_P, e_D, \bar{I}, 0)$ and $(0, 0, \underline{I}, e_J)$ to be an equilibrium; details are available from the corresponding author. Two properties from the case of continuous choices also hold here: (i) the judge's default decision does not affect marginal benefits of private search; and (ii) private parties' decision are strategically indepen-

[18] More precisely, the condition of the corner solution $r^{**} = R$ and $s^{**} = 0$ is $I'(R)v_i(e_P^*, e_D^*) - I^* e'_J(0)\gamma > 0$, $i \in \{P, D\}$, where e_P^* and e_D^* are determined by condition (19).

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dent. Therefore, we can separately consider the choice of the plaintiff and defendant.

The plaintiff will optimally exert effort e_P when the judge chooses $I = \bar{I}$, but not when $I = \underline{I}$, if the benefit from doing so outweighs the cost c_P in the former case, but not in the latter. From the first-order condition (16), the benefit of exerting e_P is proportional to $\alpha^0 \varepsilon_P S_P I$; and in the discrete-choice framework, the plaintiff's condition is[19]

$$\alpha^0 \varepsilon_P S_P e_P \bar{I} \geq c_P > \alpha^0 \varepsilon_P S_P e_P \underline{I}. \tag{26}$$

Similarly, for the defendant, the benefit of exerting e_D is proportional to $(1 - \alpha^0)\varepsilon_D S_D I$ according to condition (17). Hence, the defendant will spend c_D when $I = \bar{I}$, but not when $I = \underline{I}$, if

$$\left(1 - \alpha^0\right) \varepsilon_D S_D e_D \bar{I} \geq c_D > \left(1 - \alpha^0\right) \varepsilon_D S_D e_D \underline{I}. \tag{27}$$

For the judge, the value of information v_P and v_D depend on E_P and E_D. When both private parties exert efforts, the judge will optimally choose $(\bar{I}, 0)$ if $W^0 + \bar{I} \cdot v_i(e_P, e_D) \geq W^0 + \underline{I} \cdot v_i(e_P + (e_J/2), e_D + (e_J/2))$; and if both parties choose not to exert efforts, the judge's optimal choice is $(\underline{I}, e_J)$ if $W^0 + \underline{I} \cdot v_i((e_J/2), (e_J/2)) \geq W^0 + \bar{I} \cdot v_i(0, 0)$, where $i = P$ for $\alpha^0 > \bar{\alpha}$, and $i = D$ for $\alpha^0 \leq \bar{\alpha}$. The marginal benefit of the judge's search effort γ is also independent of the default decision as well as other players' choices, i.e.,

$$\begin{aligned} v_i\left(e_P + \frac{e_J}{2}, e_D + \frac{e_J}{2}\right) - v_i\left(e_P, e_D\right) &= v_i\left(\frac{e_J}{2}, \frac{e_J}{2}\right) - v_i(0, 0) \\ &= \gamma \cdot e_J, \quad i \in \{P, D\}. \end{aligned} \tag{28}$$

Multiple equilibria then require

$$\left(\bar{I} - \underline{I}\right) v_i\left(e_P, e_D\right) \geq \underline{I} e_J \gamma \geq \left(\bar{I} - \underline{I}\right) v_i(0, 0), \quad i \in \{P, D\}, \tag{29}$$

on the part of the judge.

To sum up, when condition (26), (27), and (29) hold, there are two equilibria $(e_P, e_D, \bar{I}, 0)$ and $(0, 0, \underline{I}, e_J)$. In the equilibrium $(e_P, e_D, \bar{I}, 0)$, the judge makes the informed decision with a higher probability, which raises private search efforts. By contrast, the lower probability of informed

[19] Upon indifference, we assume that a private party will exert the effort.

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decision in the equilibrium $(0, 0, \underline{I}, e_J)$ discourages private search. If public search is not sufficiently productive, $(e_J/2) < \min\{e_P, e_D\}$, then the equilibrium $(0, 0, \underline{I}, e_J)$ also has a lower probability of realizing θ_P^+ and θ_D^+. To avoid the "lower information quality equilibrium," the judge may want to commit to no information collection, i.e., a pure adversary system.[20] ■

6 Disclosure of the judge's *interim* beliefs

So far, information processing occurs at one time. In practice, the judge may acquire some knowledge about the case before listening to arguments or reading documents submitted by the litigants. This knowledge may change the judge's belief. In this section, we discuss whether the judge should disclose these *interim* beliefs. To focus on disclosure, we ignore the resource allocation problem, and let the judge spend all resources on information processing, with a probability $I^* = I(R)$ of an informed decision.

Before private parties search and submit the evidence, the judge (but not litigants) observes a binary *interim* signal $\tilde{\theta} \in \{\tilde{\theta}_P, \tilde{\theta}_D\}$ which correlates with the true state of nature. With probability λ, the judge observes $\tilde{\theta} = \tilde{\theta}_P$ and changes the belief from α^0 to $\tilde{\alpha}_P$, and with probability $1-\lambda$, an observation of $\tilde{\theta} = \tilde{\theta}_D$ changes the belief to $\tilde{\alpha}_D$, with $\tilde{\alpha}_D < \alpha^0 < \tilde{\alpha}_P$. The *interim* beliefs satisfy $\lambda\tilde{\alpha}_P + (1-\lambda)\tilde{\alpha}_D = \alpha^0$, i.e., they are also obtained from a Bayesian updating process.

The *interim* signal may change the judge's default decision, i.e., $\tilde{\alpha}_t$ and α^0 may fall on different sides of $\bar{\alpha}$, for some $t \in \{P, D\}$. But we maintain Assumption 1 as follows:

Assumption 2. For both $t \in \{P, D\}$, $[\tilde{\alpha}_t(1-\varepsilon_P)/\tilde{\alpha}_t(1-\varepsilon_P) + (1-\tilde{\alpha}_t)\varepsilon_D] > \bar{\alpha} > [\tilde{\alpha}_t\varepsilon_P/\tilde{\alpha}_t\varepsilon_P + (1-\tilde{\alpha}_t)(1-\varepsilon_D)]$.

The assumption requires minor belief changes and allows private efforts to affect the judicial decision making.

Conditional on the true state of nature, the *interim* signal $\tilde{\theta}$ and the signal $\hat{\theta}$ introduced in section 2 are independently distributed. Observing $\tilde{\theta}$

[20] In addition, the total search costs associated with the equilibrium $(0, 0, \underline{I}, e_J)$ are s, and those associated with the equilibrium $(e_P, e_D, \bar{I}, 0)$ are $c_P + c_D$. If $c_P + c_D < s$, then lower quality of information collection is also accompanied with higher search costs. We thank a referee for this point.

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only affects the judge's assessments about the true state, but not the conditional distribution described in (3) and (4).[21] The information structure is also common knowledge to all players. The new timing of the game includes the observation of the *interim* signal:

- The judge observes the *interim* signal, and decides whether to disclose the *interim* belief;
- private parties simultaneously determine (unobservable) e_P and e_D; and then
- the judge maintains the *interim* belief with probability $1 - I^*$, or observes Θ_P or Θ_D and forms the *ex post* belief with probability I^*, and then makes the decision accordingly.

By conditional independence, the *ex post* beliefs α_P and α_D can be computed by replacing the initial belief α^0 with the *interim* belief $\tilde{\alpha}_t$, $t \in \{P, D\}$. We state this result in the following lemma.

Lemma 3. Suppose that, given the true state $\theta \in \{P, D\}$, $\tilde{\theta}$ and $\hat{\theta}$ are independent. After observing $\tilde{\theta}_t$, $t \in \{P, D\}$, and Θ_i, $i \in \{P, D\}$, the *ex post* belief α_i is computed by replacing α^0 with $\tilde{\alpha}_t$ in expression (7) and (8).

Proof. Suppose that the true state is $\theta = P$. By conditional independence, $\Pr(\tilde{\theta}, \hat{\theta}|\theta = P) = \Pr(\tilde{\theta}|\theta = P) \cdot \Pr(\hat{\theta}|\theta = P)$ for all $\hat{\theta} \in \{\theta_P^+, \theta_P, \theta_D, \theta_D^+\}$ and $\tilde{\theta} \in \{\tilde{\theta}_P, \tilde{\theta}_D\}$. Applying Bayes' rule, after observing $\tilde{\theta} = \tilde{\theta}_t$, $t \in \{P, D\}$, and $\hat{\theta} \in \{\theta_P^+, \theta_P, \theta_D, \theta_D^+\}$ (not Θ_P or Θ_D), the belief about the true state $\theta = P$, $\Pr(\theta = P|\tilde{\theta} = \tilde{\theta}_t, \hat{\theta})$, becomes

$$\left\{\left[\Pr(\theta = P)\Pr\left(\tilde{\theta} = \tilde{\theta}_t|\theta = P\right)\Pr\left(\hat{\theta}|\theta = P\right)\right] \Big/ [\Pr(\theta = P) \Pr\left(\tilde{\theta} = \tilde{\theta}_t|\theta = P\right)\Pr\left(\hat{\theta}|\theta = P\right) + \Pr(\theta = D)\Pr\left(\tilde{\theta} = \tilde{\theta}_t|\theta = D\right) \Pr\left(\hat{\theta}|\theta = D\right)]\right\}. \tag{30}$$

Dividing both the numerator and denominator by $\Pr(\theta = P)\Pr(\tilde{\theta} = \tilde{\theta}_t|\theta = P) + \Pr(\theta = D)\Pr(\tilde{\theta} = \tilde{\theta}_t|\theta = D)$, $t \in \{P, D\}$, and using the fact that $\tilde{\alpha}_t \equiv \Pr(\theta = P|\tilde{\theta} = \tilde{\theta}_t) = \{\Pr(\theta = P)\Pr(\tilde{\theta} = \tilde{\theta}_t|\theta =$

[21] One may argue that prior exposure to case relevant knowledge would also enhance the judge's ability of information processing. Our analysis here does not depend on the level of I^*, and will hold for $I^* = 1$.

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$P)/[\Pr(\theta = P)\Pr(\tilde{\theta} = \tilde{\theta}_t|\theta = P) + \Pr(\theta = D)\Pr(\tilde{\theta} = \tilde{\theta}_t|\theta = D)]\}$, the belief can be expressed as

$$\Pr(\theta = P|\tilde{\theta} = \tilde{\theta}_t, \hat{\theta}) = \frac{\tilde{\alpha}_t \Pr(\hat{\theta}|\theta = P)}{\tilde{\alpha}_t \Pr(\hat{\theta}|\theta = P) + (1 - \tilde{\alpha}_t)\Pr(\hat{\theta}|\theta = D)}. \quad (31)$$

That is, we can compute this updated belief by replacing the initial belief α^0 with the *interim* belief in the formula of computing the updated belief after observing $\hat{\theta}$.

To compute the updated belief of observing both the *interim* signal $\tilde{\theta}$ and pro-plaintiff evidence $\Theta_P = \{\theta_P^+, \theta_P\}$, note that $\Pr(\tilde{\theta}, \Theta_P|\theta = P) = \Pr(\tilde{\theta}, \theta_P^+|\theta = P) + Pr(\tilde{\theta}, \theta_P|\theta = P)$, for the realization of θ_P^+ and θ_P are mutually exclusive. Following the same steps and we obtain the updated beliefs by replacing the initial belief with the *interim* belief in the expression (7) and (8). ■

First consider the effect of disclosure on private search. A binary *interim* signal implies that we only need to consider full disclosure or no disclosure. If the judge only selectively discloses, say, $\tilde{\alpha}_P$, then the "silence" or non-disclosure is equivalent to disclosing the belief $\tilde{\alpha}_D$. As long as the judge does not falsify the belief, e.g., announcing $\tilde{\alpha}_D$ when it is actually $\tilde{\alpha}_P$, which is excluded from the analysis, partial disclosure has the same effect as full disclosure.

If the judge truthfully discloses the *interim* belief, the analysis proceeds in the same manner as in section 4, with a replacement of the initial belief α^0 by the prevailing *interim* belief $\tilde{\alpha}_t$, $t \in \{P, D\}$. We can apply Proposition 1 to obtain the private search efforts $e_P^*(\tilde{\alpha}_t)$ and $e_D^*(\tilde{\alpha}_t)$, determined by condition (19), as functions of belief $\tilde{\alpha}_t$, $t \in \{P, D\}$.

Suppose that the judge does not disclose *interim* beliefs. Without knowing the prevailing belief, litigants reason that, to the extent that the judge understands the evidence, their submission will be incorporated with the belief $\tilde{\alpha}_P$ with probability λ, and with the belief $\tilde{\alpha}_D$ with probability $1 - \lambda$. They are concerned with, *on average*, what's the belief the judge holds. By the property of $\lambda\tilde{\alpha}_P + (1 - \lambda)\tilde{\alpha}_D = \alpha^0$, private parties will exert efforts according to the *ex ante* belief α^0. The private search efforts are $e_P^*(\alpha^0)$ and $e_D^*(\alpha^0)$ under no disclosure.[22]

[22] Similar to the previous analysis, the *interim* signal may affect he judge's default decision, but not private search incentives. See the proof of Proposition 3.

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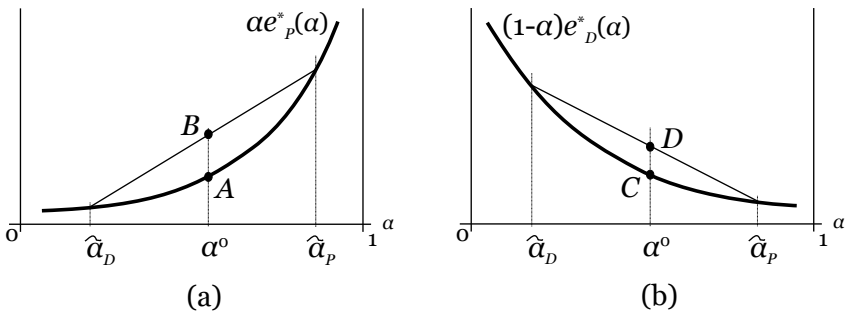


Figure 3: Convexity and disclosure

For the optimal disclosure policy, intuitively, an informed decision still entails mistakes, and private search efforts help reduce these mistakes. Referring to Table 1, the judge may mistakenly rule for the defendant even though the true state is $\theta = P$. This occurs when the judge observes Θ_D at this state, with a probability proportional to $\alpha(1 - e_P)\varepsilon_P$. Higher e_P reduces the likelihood of this error, and disclosure affects welfare through its impact on private search efforts.

Under no disclosure, the plaintiff's search effort remains at $e_P^*(\alpha^0)$, regardless of the *interim* belief. In expectation, the likelihood that the plaintiff's effort improves welfare is proportional to $\lambda\tilde{\alpha}_P e_P^*(\alpha^0)+(1-\lambda)\tilde{\alpha}_D e_P^*(\alpha^0) = [\lambda\tilde{\alpha}_P + (1-\lambda)\tilde{\alpha}_D]e_P^*(\alpha^0) = \alpha^0 e_P^*(\alpha^0)$. Under disclosure, the plaintiff chooses $e_P^*(\tilde{\alpha}_t)$, $t \in \{P, D\}$, and this likelihood is proportional to $\lambda\tilde{\alpha}_P e_P^*(\tilde{\alpha}_P) + (1-\lambda)\tilde{\alpha}_D e_P^*(\tilde{\alpha}_D)$. Because $\tilde{\alpha}_P > \alpha^0 > \tilde{\alpha}_D$ and e_P^* is strictly increasing in α,[23] the plaintiff's efforts exhibit the relationship $e_P^*(\tilde{\alpha}_P) > e_P^*(\alpha^0) > e_P^*(\tilde{\alpha}_D)$. Relative to no disclosure, disclosing $\tilde{\alpha}_P$ ($\tilde{\alpha}_D$) raises (reduces, respectively) the plaintiff's search efforts. *On average*, disclosure is socially beneficial if the function $\alpha e_P^*(\alpha)$ is strictly convex in α. In Figure 3(a), the function $\alpha e_P^*(\alpha)$ is strictly increasing and convex in α, the point A and B correspond to $\alpha^0 e_P^*(\alpha^0)$ and $\lambda\tilde{\alpha}_P e_P^*(\tilde{\alpha}_P) + (1-\lambda)\tilde{\alpha}_D e_P^*(\tilde{\alpha}_D)$, respectively. Strict convexity, by definition, guarantees that point B is higher than point A, i.e., $\lambda\tilde{\alpha}_P e_P^*(\tilde{\alpha}_P) + (1-\lambda)\tilde{\alpha}_D e_P^*(\tilde{\alpha}_D) > \alpha^0 e_P^*(\alpha^0)$.

Similarly, the defendant's search effort e_D helps avoid the error of ruling for the plaintiff when the true state is $\theta = D$, which occurs when the judge observes Θ_P (see Table 1). The relevant part of consideration

[23] By condition (19), $de_P^*/d\alpha = (\varepsilon_P S_P I^*)/c_P'' > 0$.

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is $(1-\alpha)e_D^*(\alpha)$, the probability of state $\theta = D$ times the defendant's effort. The effort e_D^* is strictly decreasing in α,[24] which implies a strictly decreasing function function $(1-\alpha)e_D^*(\alpha)$ as shown in Figure 3(b). In the figure, point C represents the value under no disclosure, $(1-\alpha^0)e_D^*(\alpha^0)$, and point D the value under disclosure, $\lambda(1-\tilde{\alpha}_P)e_D^*(\tilde{\alpha}_P) + (1-\lambda)(1-\tilde{\alpha}_D)e_D^*(\tilde{\alpha}_D)$. Strict convexity ensures that point D is higher than point C, i.e., disclosure improves welfare.

The functions $\alpha e_P^*(\alpha)$ and $(1-\alpha)e_D^*(\alpha)$ are strictly convex if, respectively,

$$\frac{d^2\alpha e_P^*(\alpha)}{d\alpha^2} = 2\frac{de_P^*}{d\alpha} + \alpha\frac{d^2e_P^*}{d\alpha^2} > 0 \tag{32}$$

$$\text{and} \quad \frac{d^2(1-\alpha)e_D^*(\alpha)}{d\alpha^2} = -2\frac{de_D^*}{d\alpha} + (1-\alpha)\frac{d^2e_D^*}{d\alpha^2} > 0, \tag{33}$$

where $de_P^*/d\alpha > 0 > de_D^*/d\alpha$, and

$$\frac{d^2e_P^*}{d\alpha^2} = -\frac{\varepsilon_P S_P I^*}{\left(c_P''\right)^2}c_P'''\frac{de_P^*}{d\alpha} \quad \text{and} \quad \frac{d^2e_D^*}{d\alpha^2} = \frac{\varepsilon_D S_D I^*}{\left(c_D''\right)^2}c_D'''\frac{de_D^*}{d\alpha}. \tag{34}$$

We obtain strict convexity if c_P''' and $c_D''' \leq 0$, or, in the case of $c_i''' > 0$ for some $i \in \{P, D\}$, the first-order effect of α dominates the second-order effect.

Proposition 3. (Disclosure) If $\alpha e_P^*(\alpha)$ and $(1-\alpha)e_D^*(\alpha)$ are strictly convex in α, then it is optimal for the judge to disclose the *interim* belief.

Strict convexity holds when $c_i''' \leq 0$, or when the first-order effect of α on e_i^* dominates the second-order effect, $i \in \{P, D\}$.

Proof. In the appendix. ■

7 Conclusion

In this paper, we incorporate the judge's efforts of processing information into a litigation model, and obtain two results that, we believe, have important policy implications. First, we show that diverting court resources from helping the judge understand technical issues to information collection undermines litigants' incentives, and may reduce the quality of judicial

[24] By condition (19), $de_D^*/d\alpha = -(\varepsilon_D S_D I^*)/c_D'' < 0$.

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decision making in equilibrium. And second, under a fairly general condition (namely, the first-order effect of belief on private search outweighs the second-order effect), disclosing the judge's *interim* assessments of the case is socially optimal.

For future research, with the establishment of the IP court in Taiwan, an important issue concerns the role of Technical Examination Officers (TEO, 技術審查官). In each patent litigation, a TEO is assigned to the judge to help understand technical issues of the case, collect information pertinent to the case, and may directly interact with litigants as instructed by the judge.[25] In terms of our model, these professional helps crucially affect the judge' information processing.[26] A hotly debated concern is the so-called "shadow judge," namely, the (informal) delegation of the judical decision power to the technical examination officer.[27] By incorporating this delegation element into the model, we could address questions such as how to prevent the technical examination officer from exploiting his informational advantage,

[25] The system of TEO is borrowed from Japan and South Korea; see press release of Judicial Yuan (司法院) on August 9, 2013, available in Chinese at http://jirs.judicial.gov.tw/GNNWS/download.asp?sdMsgId=32213 (visited on 06/06/2020). Article 4 of Intellectual Property Case Adjudication Act (智慧財產案件審理法) states that: *"The court may, whenever necessary, request a Technical Examination Officer to perform the following duties: 1. Ask questions or explain to the parties pertaining to factual and legal issues based on the professional knowledge, in order to clarify the disputes in action; 2. ask questions directly to witnesses or expert witnesses; 3. state opinions on the case to the judge; 4. assist in evidence-taking in the event of preservation of evidence; and 5. assist in injunctive procedures or compulsory enforcement procedures."*

[26] Another way to affect the judge is through the formation of *interim* beliefs.

[27] See Yachi Chiang, "Are Technical Examination Officers Shadow Judges?" (智財技審官是影子法官?) *China Times*, August 16, 2013 (available in Chinese at http://www.chinatimes.com/newspapers/20130816000884-260109; visited on 06/06/2020); and press release of Judicial Yuan on August 9, 2013 (in footnote 25). In principle, a major benefit of technical examination officers is to help the judge understand the background information so as to quickly grasp the essence of the case. In practice, the line between background information and case-specific materials is not always clear-cut. Note (1997) also raises concerns about the use of technical advisors in a common law court with a generalist judge, including (i) the judge may delegate the decision making power to the advisor; (ii) the advisor may not be neutral; and (iii) *"just as the use of court-appointed expert witness conflicts with the adversarial ideal that the parties should be responsible for producing all evidence to the jury, technical advisors may interfere with the adversarial process by providing evidence directly to the judge"* (citation omitted).

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and how to properly incentivize the technical examination officer (Aghion and Tirole, 1997).

Lastly, different jurisdictions may adopt different solutions to the same problem.[28] In the future, it would be interesting to evaluate other alternatives, and to investigate the optimal design of the litigation process. Such an analysis would give us a deeper understanding of the patent system, and improve judicial decision making when the judge's understanding of the technical knowledge is crucial.

Appendix: Proof of Proposition 3

First consider private search under no disclosure. The probability ρ is a function of belief α as well as e_P and e_D; see expression (6).

- When $\tilde{\alpha}_D > \bar{\alpha}$, the default decision is to rule for the plaintiff for both $\tilde{\alpha}_P$ and $\tilde{\alpha}_D$. Only an observation of Θ_D will change the decision to rule for the defendant, which reduces the plaintiff's payoff by S_P, and increases the defendant's payoff by S_D. Given that the judge understands the evidence (with probability I^*), the probability of this event, $1 - \rho(\tilde{\alpha}_t)$, depends on the prevailing *interim* belief $\tilde{\alpha}_t$, $t \in \{P, D\}$. Taking into account the probability distribution of *interim* beliefs, the expected payoff is $\lambda\{b_P - I^*S_P[1-\rho(\tilde{\alpha}_P)] - c_P\} + (1-\lambda)\{b_P - I^*S_P[1-\rho(\tilde{\alpha}_D)] - c_P\} = b_P - I^*S_P + I^*S_P[\lambda\rho(\tilde{\alpha}_P) + (1-\lambda)\rho(\tilde{\alpha}_D)] - c_P$ for the plaintiff, and $\lambda\{-l_D + I^*S_D[1-\rho(\tilde{\alpha}_P)] - c_D\} + (1-\lambda)\{-l_D + I^*S_D[1-\rho(\tilde{\alpha}_D)] - c_D\} = -l_D + I^*S_D - I^*S_D[\lambda\rho(\tilde{\alpha}_P) + (1-\lambda)\rho(\tilde{\alpha}_D)] - c_D$ for the defendant.
- When $\tilde{\alpha}_P \leq \bar{\alpha}$, the default decision is to rule for the defendant for both $\tilde{\alpha}_P$ and $\tilde{\alpha}_D$. Only an observation of Θ_P will the judge change to rule for the plaintiff. The plaintiff's expected payoff is $\lambda[-l_P +$

[28] For instance, the IP court in Taiwan has jurisdiction at both the first instance and appeal level. CAFC and IPHC, as suggested by the name, are appeal courts. In addition, in Germany patent cases are heard by judges with strong technical backgrounds. In the United States, private parties assume the major role to "educate" the judge and jury by, e.g., providing expert witness. Although Federal Rule of Evidence 706 authorizes a judge to appoint experts, its use remains uncommon. (Rule 706 is available on https://www.law.cornell.edu/rules/fre/rule_706; visited on 06/06/2020.) See Note (1997) for a discussion of technical advisors in the U.S.; and Goldstein, Bird, and Woon (2006) for an overview of IP specialized courts in other countries.

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$I^*S_P\rho(\tilde{\alpha}_P) - c_P] + (1-\lambda)[-l_P + I^*S_P\rho(\tilde{\alpha}_D) - c_P] = -l_P + I^*S_P[\lambda\rho(\tilde{\alpha}_P) + (1-\lambda)\rho(\tilde{\alpha}_D)] - c_P$, and that of the defendant is $\lambda[b_D - I^*S_D\rho(\tilde{\alpha}_P) - c_D] + (1-\lambda)[b_D - I^*S_D\rho(\tilde{\alpha}_D) - c_D] = b_D - I^*S_D[\lambda\rho(\tilde{\alpha}_P) + (1-\lambda)\rho(\tilde{\alpha}_D)] - c_D$.

- And, lastly, when $\tilde{\alpha}_D \leq \bar{\alpha} < \tilde{\alpha}_P$, without further information, the judge will rule for the plaintiff when holding belief $\tilde{\alpha}_P$, and rule for the defendant when holding belief $\tilde{\alpha}_D$. Observing Θ_D in the former case and Θ_P in the latter change the judge's decision for the opposite party. The plaintiff's payoff is $\lambda\{b_P - I^*S_P[1-\rho(\tilde{\alpha}_P)] - c_P\} + (1-\lambda)[-l_P + I^*S_P\rho(\tilde{\alpha}_D) - c_P] = [\lambda(b_P - I^*S_P) - (1-\lambda)l_P] + I^*S_P[\lambda\rho(\tilde{\alpha}_P) + (1-\lambda)\rho(\tilde{\alpha}_D)] - c_P$, while the defendant gets $\lambda\{-l_D + I^*S_D[1-\rho(\tilde{\alpha}_P)] - c_D\} + (1-\lambda)[b_D - I^*S_D\rho(\tilde{\alpha}_D) - c_D] = -\lambda(l_D - I^*S_D) + (1-\lambda)b_D - I^*S_D[\lambda\rho(\tilde{\alpha}_P) + (1-\lambda)\rho(\tilde{\alpha}_D)] - c_D$.

In all these cases, a litigant's incentives to search depend on $\lambda\rho(\tilde{\alpha}_P) + (1-\lambda)\rho(\tilde{\alpha}_D)$, which is equal to $\rho(\alpha^0)$:

$$\lambda\rho\left(\tilde{\alpha}_P\right) + (1-\lambda)\rho\left(\tilde{\alpha}_D\right) \tag{35}$$

$$= \lambda\left\{\tilde{\alpha}_P\left[1-(1-e_P)\,\varepsilon_P\right] + (1-\tilde{\alpha}_P)\,(1-e_D)\,\varepsilon_D\right\}$$

$$+ (1-\lambda)\left\{\tilde{\alpha}_D\left[1-(1-e_P)\varepsilon_P\right] + (1-\tilde{\alpha}_D)\,(1-e_D)\,\varepsilon_D\right\} \tag{36}$$

$$= \alpha^0\left[1-(1-e_P)\,\varepsilon_P\right] + \left(1-\alpha^0\right)(1-e_D)\,\varepsilon_D = \rho\left(\alpha^0\right). \tag{37}$$

Not knowing the *interim* beliefs, both litigants will exert search efforts according to the *ex ante* belief α^0.

Consider the optimal disclosure policy. To facilitate the presentation, denote $\tilde{W}_P \equiv W(\tilde{\alpha}_P)$ as the expected welfare when the judge makes the default decision according to the *interim* belief $\tilde{\alpha}_P$, i.e., without observing Θ_P or Θ_D. Referring to expression (5), $\tilde{W}_P = W_P(\tilde{\alpha}_P)$ if $\tilde{\alpha}_P > \bar{\alpha}$, and $W_D(\tilde{\alpha}_P)$ if $\tilde{\alpha}_P \leq \bar{\alpha}$. Similarly, $\tilde{W}_D \equiv W(\tilde{\alpha}_D)$ is the welfare when the judge makes the default decision based on belief $\tilde{\alpha}_D$. Also note that the expected welfare of an informed decision (W^I) is evaluated at private search efforts as well as the prevailing *interim* belief; see expression (9).[29]

Under the policy of no disclosure, litigants exert search effort $e_i^*(\alpha^0), i \in \{P, D\}$, and the expected welfare is $\lambda[(1-I^*)\tilde{W}_P + I^*W^I(\tilde{\alpha}_P, e_P^*(\alpha^0), e_D^*$

[29] To save on the notation, here we consider W^I as a function of α, no specific to the *ex ante* belief α^0.

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$(\alpha^0))] + (1-\lambda)[(1-I^*)\tilde{W}_D + I^* W^I(\tilde{\alpha}_D, e_P^*(\alpha^0), e_D^*(\alpha^0))]$. By contrast, learning the *interim* belief allows litigants to respond; the search efforts are $e_i^*(\tilde{\alpha}_t)$, i and $t \in \{P, D\}$, with expected welfare $\lambda[(1-I^*)\tilde{W}_P + I^* W^I(\tilde{\alpha}_P, e_P^*(\tilde{\alpha}_P), e_D^*(\tilde{\alpha}_P))] + (1-\lambda)[(1-I^*)\tilde{W}_D + I^* W^I(\tilde{\alpha}_D, e_P^*(\tilde{\alpha}_D), e_D^*(\tilde{\alpha}_D))]$. Disclosure affects welfare via private search incentives, and the relevant parts for comparison are $\lambda W^I(\tilde{\alpha}_P, e_P^*(\alpha^0), e_D^*(\alpha^0)) + (1-\lambda) W^I(\tilde{\alpha}_D, e_P^*(\alpha^0), e_D^*(\alpha^0))$ (without disclosure) and $\lambda W^I(\tilde{\alpha}_P, e_P^*(\tilde{\alpha}_P), e_D^*(\tilde{\alpha}_P)) + (1-\lambda) W^I(\tilde{\alpha}_D, e_P^*(\tilde{\alpha}_D), e_D^*(\tilde{\alpha}_D))$ (with disclosure). Replacing α^0 in expression (13) with the proper *interim* belief, and by the fact that $\lambda\tilde{\alpha}_P + (1-\lambda)\tilde{\alpha}_D = \alpha^0$, the former is

$$\begin{aligned} &\lambda W^I\left(\tilde{\alpha}_P, e_P^*\left(\alpha^0\right), e_D^*\left(\alpha^0\right)\right) + (1-\lambda) W^I\left(\tilde{\alpha}_D, e_P^*\left(\alpha^0\right), e_D^*\left(\alpha^0\right)\right) \quad (38)\\ &\quad = \alpha^0 \bar{w}_P + \left(1-\alpha^0\right)\bar{w}_D - \alpha^0 \varepsilon_P \triangle_P - \left(1-\alpha^0\right)\varepsilon_D \triangle\\ &\qquad + \varepsilon_P \triangle_P \left[\lambda\tilde{\alpha}_P e_P^*\left(\alpha^0\right) + (1-\lambda)\tilde{\alpha}_D e_P^*\left(\alpha^0\right)\right]\\ &\qquad + \varepsilon_D \triangle_D \left[\lambda\left(1-\tilde{\alpha}_P\right) e_D^*\left(\alpha^0\right) + (1-\lambda)\left(1-\tilde{\alpha}_D\right) e_D^*\left(\alpha^0\right)\right], \quad (39)\end{aligned}$$

and the latter

$$\begin{aligned} &\lambda W^I\left(\tilde{\alpha}_P, e_P^*\left(\tilde{\alpha}_P\right), e_D^*\left(\tilde{\alpha}_P\right)\right) + (1-\lambda) W^I\left(\tilde{\alpha}_D, e_P^*\left(\tilde{\alpha}_D\right), e_D^*\left(\tilde{\alpha}_D\right)\right) \quad (40)\\ &\quad = \alpha^0 \bar{w}_P + \left(1-\alpha^0\right)\bar{w}_D - \alpha^0 \varepsilon_P \triangle_P - \left(1-\alpha^0\right)\varepsilon_D \triangle\\ &\qquad + \varepsilon_P \triangle_P \left[\lambda\tilde{\alpha}_P e_P^*\left(\tilde{\alpha}_P\right) + (1-\lambda)\tilde{\alpha}_D e_P^*\left(\tilde{\alpha}_D\right)\right]\\ &\qquad + \varepsilon_D \triangle_D \left[\lambda\left(1-\tilde{\alpha}_P\right) e_D^*\left(\tilde{\alpha}_D\right) + (1-\lambda)\left(1-\tilde{\alpha}_D\right) e_D^*\left(\tilde{\alpha}_D\right)\right]. \quad (41)\end{aligned}$$

It suffices to compare the last two terms.

By $\lambda\tilde{\alpha}_P e_P^*(\alpha^0) + (1-\lambda)\tilde{\alpha}_D e_P^*(\alpha^0) = [\lambda\tilde{\alpha}_P + (1-\lambda)\tilde{\alpha}_D] e_P^*(\alpha^0) = \alpha^0 e_P^*(\alpha^0)$, and $\lambda(1-\tilde{\alpha}_P) e_D^*(\alpha^0) + (1-\lambda)(1-\tilde{\alpha}_D) e_D^*(\alpha^0) = [\lambda(1-\tilde{\alpha}_P) + (1-\lambda)(1-\tilde{\alpha}_D)] e_D^*(\alpha^0) = (1-\alpha^0) e_D^*(\alpha^0)$, if both $\alpha e_P^*(\alpha)$ and $(1-\alpha) e_D^*(\alpha)$ are strictly convex in α, we must have $\lambda\tilde{\alpha}_P e_P^*(\tilde{\alpha}_P) + (1-\lambda)\tilde{\alpha}_D e_P^*(\tilde{\alpha}_D) > [\lambda\tilde{\alpha}_P + (1-\lambda)\tilde{\alpha}_D] e_P^*(\lambda\tilde{\alpha}_P + (1-\lambda)\tilde{\alpha}_D) = \alpha^0 e_P^*(\alpha^0)$, and $\lambda(1-\tilde{\alpha}_P) e_D^*(\tilde{\alpha}_P) + (1-\lambda)(1-\tilde{\alpha}_D) e_D^*(\tilde{\alpha}_D) > \{1 - [\lambda\tilde{\alpha}_P + (1-\lambda)\tilde{\alpha}_D]\} e_D^*(\lambda\tilde{\alpha}_P + (1-\lambda)\tilde{\alpha}_D) = (1-\alpha^0) e_D^*(\alpha^0)$, and so disclosure is the optimal policy.

Since $d[\alpha e_P^*(\alpha)]/d\alpha = e_P^* + \alpha \cdot (de_P^*/d\alpha)$ and $d[(1-\alpha) e_D^*(\alpha)]/d\alpha = -e_D^* + (1-\alpha) \cdot (de_D^*/d\alpha)$, convexity requires

$$\frac{d^2 \alpha e_P^*(\alpha)}{d\alpha^2} = 2\frac{de_P^*}{d\alpha} + \alpha\frac{d^2 e_P^*}{d\alpha^2} > 0 \quad (42)$$

$$\text{and} \quad \frac{d^2(1-\alpha) e_D^*(\alpha)}{d\alpha^2} = -2\frac{de_D^*}{d\alpha} + (1-\alpha)\frac{d^2 e_D^*}{d\alpha^2} > 0. \quad (43)$$

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From the first-order conditions (19), $de_P^*/d\alpha = (\varepsilon_P S_P I^*)/c_P'' > 0$ and $de_D^*/d\alpha = -(\varepsilon_D S_D I^*)/c_D'' < 0$, and

$$\frac{d^2 e_P^*}{d\alpha^2} = -\frac{\varepsilon_P S_P I^*}{\left(c_P''\right)^2} c_P''' \frac{de_P^*}{d\alpha} \quad \text{and} \quad \frac{d^2 e_D^*}{d\alpha^2} = \frac{\varepsilon_D S_D I^*}{\left(c_D''\right)^2} c_D''' \frac{de_D^*}{d\alpha}. \tag{44}$$

Therefore, if c_P''' and $c_D''' \leq 0$, including the quadratic cost function, or $c_i''' > 0$ for some $i \in \{P, D\}$, but the second-order effect of α on e_i^* does not outweigh the first-order effect, then convexity is guaranteed.

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論專業案件之審理

邱敬淵
國立台北大學經濟系
李素華
國立台灣大學法律系
王怡蘋
國立台北大學法律系

專業案件的審理仰賴法官對於技術細節的掌握, 而其理解程度又受到法院的人力、時間等資源限制。本文將法官的技術理解決策納入訴訟模型, 指出若法官花費更多心力於辨析技術細節, 能促使訴訟雙方提出更多證據, 進而提昇裁判品質。根據此基本性質, 本文進一步分析兩項議題: 第一, 挪用有限法院資源於蒐集證據, 將使法官理解技術程度下降, 並削弱訴訟雙方提供證據的誘因。若法院蒐證能力不足, 整體裁判品質將會下降; 第二, 若法官於審理過程中能揭露心證, 可讓訴訟雙方據此調整蒐證策略, 並在通常可滿足的數學條件下, 提升社會福利。

關鍵詞: 心證開示, 貝氏說服, 法院審理
JEL 分類代號: D83, K41, O34

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