Working Paper Series
No. 14

# Strategic behavior at trial

## The production, reporting, and evaluation of complex evidence

Anabela Botelho

September 2001

Núcleo de Investigação em Microeconomia Aplicada
Universidade do Minho

# Strategic behavior at trial
## The production, reporting, and evaluation of complex evidence

Anabela Botelho*
Universidade do Minho and NIMA

September 2001

**Abstract**

Recent game-theoretic analyses of the adversarial process have focused on the ability of courts to render accurate verdicts in light of selectively reported evidence. This paper generalizes previous work by developing a game where the court's decision to weigh evidence and litigants' information-gathering and reporting strategies are endogenously determined, and examines the effects on the players' equilibrium strategies of varying the informational endowments of the litigants concerning the true value of the parameter under dispute. We find that litigants' strategies are driven by their knowledge of the court's potential strategic behavior and prior beliefs, which are non-neutral with respect to trial results.

*Keywords*: adversarial process, information provision, weighing of evidence
*JEL classification*: K40, K41

* Escola de Economia e Gestão, Universidade do Minho, Campus de Gualtar, 4710-057 Braga, Portugal. Tel.:+351-253-604538; fax:+351-253-676375; e-mail:botelho@eeg.uminho.pt

## 1. Introduction

Recent game-theoretic analyses of the adversarial process have focused on the ability of courts to render accurate verdicts in light of selectively reported evidence. Milgrom and Roberts (1986) consider the problem of a decision-maker who must rely on information provided by interested parties to reach a decision. They find that competition in information provision among adversaries with sufficiently opposed interests allows even an unsophisticated decision-maker, who fails to recognize the strategic incentives of the parties, to reach a full-information decision.

Froeb and Kobayaschi (1996) expanded this analysis to allow for decision-maker bias and costly evidence production. They model a case of civil litigation where the defendant's liability is represented by the mean of a binomial distribution, $p$, and both parties present evidence to a jury drawn, at a constant marginal cost, from this distribution. Using the analogy of a coin-flipping experiment to motivate this representation, where the number of heads is evidence favorable to the plaintiff and the number of tails is evidence favorable to the defendant, Froeb and Kobayaschi assume that the jury is naive in that it views evidence as a random sample when in fact it is selectively reported. In addition to being naive, the jury is also biased by the beta prior beliefs over the unknown (to the jury, but not to each litigant) value of $p$ that it carries into the courtroom. The jury's rule to infer the value of $p$, known to the litigants, consists in updating its prior beliefs in light of evidence reported by both litigants, and the estimator of $p$ is the mean of the posterior distribution. Froeb and Kobayaschi illustrate the litigants' optimal reporting strategies, and the jury's estimate of $p$ by means of a numerical example for several possible $p$ values and jury's priors, and find that the litigants always report the true value of $p$, which is also accurately estimated by the jury. They conclude that the Milgrom and Roberts's finding that competition among litigants allows a naïve decision-maker to reach a full-information decision carries over to settings where the decision-maker is biased in favor of one party.[1]

This result has been recently challenged by Farmer and Pecorino (2000) who consider an alternative specification of jury bias in Froeb and Kobayaschi' model. In particular, they transform the jury's estimator of the parameter $p$ to allow for a multiplicative, rather than additive, form of bias, and introduce scale effects in the perceptions of arguments by the jury. It turns out that under this specification the jury bias is *not* eliminated by the competitively produced evidence of the litigants. Thus, in contrast to previous findings, Farmer and Pecorino conclude that under certain circumstances the adversarial presentation of evidence can actually exacerbate the initial bias carried by the decision-maker into the courtroom.

Although the foregoing analyses generate different predictions concerning the accuracy of the adversarial trial result, they all share a common core: all involve the assumption that litigants only report information favorable to their own case, and that the court has a known predetermined decision rule. The conventional wisdom that litigants only report favorable evidence becomes less clear, however, if one views the court as a participant in the process: if the adversarial system might initially encourage advocates to report only favorable information, then courts might understand this and might compensate for it. Given this, it is not clear that litigants benefit by reporting only extreme positions; perhaps defendants and/or plaintiffs might actually benefit by revealing unfavorable information.[2]

[1] Decision-maker bias has played a prominent role in the ongoing debate concerning the ability of the adversarial system of justice to produce fair and accurate results, particularly in tort cases involving complex damage calculations. See, for example, Cecil *et al*. (1991).
[2] For example, Thornton and Ward (1999) point out that, where damages are at issue, plaintiffs often prefer a conservative damage estimate with a high probability of acceptance over an inflated damage estimate that might carry credibility problems.

It is our purpose here to provide a more general game of the adversarial process by relaxing some unappealing assumptions in previous analyses. First, we relax the assumption that the parties in an adversarial setting only report information favorable to their case. By doing so, we can determine which patterns of optimal reporting emerge as a consequence of equilibrium play. Second, we relax the assumption that the decision-maker (the judge or jury, hereafter just "the court"[3]) acts as a naive automaton with one predetermined decision rule. In our characterization of the adversarial process the court is an active player in the game with a set of possible rules to estimate the parameter of interest. The court can opt to rely entirely on the information provided by a court-appointed expert, to rely on the information provided by the litigants, or to use both.[4] Moreover, the way the court weights the evidence provided by the litigants can take a number of forms: the court can rely on the information provided by both litigants, or it can rely entirely on the information provided by a single interested party. Thus, we model *strategic behavior on the part of the court*. By relaxing these two assumptions resulting outcome of the adversarial process is left to the interaction of the participants. Hence, any reporting strategies are represented as an equilibrium outcome, and the court's approach to infer the value of the parameter of interest also is an equilibrium outcome.

[3] Whether juries and judges differ in their decisions is the subject of a heated debate that will not be addressed here. Critics of the American tort system argue that the jury is the primary flaw in the legal procedures through which injured parties seek redress. A major criticism of civil juries is that laypersons are not competent to decide the complex legal and factual issues germane to many trials. See Cecil *et al*. (1991). Recently, concerns about jury competence have become more acute as jurors consider complex questions of damages in medical malpractice, environmental tort and product liability cases. See, for example, Greene *et al.* (1991). Generally those who argue against the jury propose that the jury's work should be done by judges, who have legal training and experience in the logic of evidence. However, verdict studies point to a high rate of judge-jury agreement, suggesting that the jury system works as well as judge decision making. See, for example, Vidmar and Rice (1993).

[4] This feature of the analysis sits well with the rules of evidence that govern the testimony of expert witnesses in federal American courts. In 1975 Congress provided the express right of a court to appoint expert witnesses to civil cases. Rule 706 of the Federal Rules of Evidence states that a "court may appoint any expert witness agreed upon by the parties, and may appoint expert witnesses of its own selection", and following *Daubert v. Merrell Dow Pharmaceuticals*, 113 S. Ct. 2786 (1993) judges are required to assume a "gatekeeper" role - assessing the qualifications of experts, the relevance of their testimony, and the scientific soundness of their methodology - before allowing the experts to testify.

Finally, we model situations where the litigants know the true value of the parameter under dispute and situations where the litigants do not know the true value of the parameter under dispute. The latter assumption is intended to capture those instances where *ex ante* quantification of damages is difficult. This is typically the case in environmental damage contexts where non-use values[5] have legal standing and in the areas of product liability and medical malpractice where noneconomic losses[6] are typically present. In fact, in the environmental sphere, as well as in product liability and medical malpractice cases, we typically find substantial uncertainty as to the amount of damages caused. In these cases, litigants often possess a wide degree of latitude in calculating damages, and it is not obvious that any reporting strategies or the damage payment likely to be used by courts readily transfer to this setting from one where damages are directly measurable and readily quantifiable.

The organization of the paper proceeds as follows. The section below presents the model. The behavioral properties of the model are evaluated numerically in Section 3, and Section 4 concludes.

## 2. The model

### *2.1. General framework*

We model the behavior of three risk-neutral players, the court, the plaintiff, and the defendant at the trial stage. The context is a hypothetical product liability lawsuit where the only issue to be determined is the amount of damages for which the defendant will

[5] Since the *Ohio v. U.S. Department of the Interior* case, 880 F.2d 432, 438 (D.C. Cir. 1989), non-use values, which represent the monetary worth of environmental resources not related to current use, gained legal standing as compensable damages. See, for example, Ward and Duffield (1992).

[6] Noneconomic damages, generally referred to as “pain and suffering”, involve monetary compensation for the injury to the intangible, subjective state of the plaintiff’s life. Noneconomic damages include compensation for the physical pain felt by the plaintiff at the time of the injury, physical pain during recuperation, or physical pain that will continue into the future. They can also include emotional pain such as fear and anxiety. See, for example, Viscusi (1988).

be held liable.[7] It is assumed that the court and the litigants interact only once, so that issues of reputation do not arise.[8] It is also assumed that the litigants can withhold information, but that the court can freely verify anything that is reported to it.[9] The model also addresses the potential for bias in both the court-appointed and adversarial systems.[10] The bias is characterized by a prior probability distribution over the unknown value of damages.

In the model, the court's objective is to estimate the true damage as accurately as possible given all available information. The interested parties' problem is to estimate the amount of damages and report those estimates to the court who will combine them in some way in order to determine the amount of damages to be awarded to the plaintiff. In this context, and given the assumption of risk-neutrality, the plaintiff's problem is to report a damage estimate so as to maximize his payoff at trial, and the defendant's problem is to report a damage estimate so as to minimize his payout at trial.

To clarify the decision-theoretic approach to point estimation in an adversarial setting, we use the analogy of a sampling inspection scenario of quality control modified by the adversarial nature of the game. In the context of the idealized product

---

[7] In the model below, the actual level of damages caused by the defendant is captured by a parameter $\theta$, but this parameter could also be interpreted either as the probability that the defendant will be held liable or as the defendant's level of fault under a negligence tort standard. In both cases, and in general, it is the expected damage award that counts. Since the expected damage award equals the damage award times likelihood of liability, then one of the models corresponds to a scenario where the parties know that the likelihood of liability is unity, and the other model corresponds to a scenario where the parties know the realized damage. We will proceed with analyzing the case wherein liability is clear and damages are at issue, recognizing that the results readily transfer to other settings.

[8] This assumption implies that the court and the litigants are uninterested in setting precedents for future cases at the cost of reduced payoffs in the present case. See Rubinfeld (1984) and Sobel (1985) for models where parties are concerned about future litigation.

[9] By doing so, we retain the assumption of Milgrom and Roberts (1986) and Froeb and Kobayaschi (1996) concerning the decision-maker's ability to verify information provided by interested parties. In Milgrom and Roberts's game, this assumption implies that the seller can verifiably report that his product meets or exceeds a certain standard, but at the same time he can simply fail to mention a more relevant or stringent standard that the product does not meet. In Froeb and Kobayaschi's game, this assumption implies that the jury can verify that the evidence is drawn from a certain distribution but cannot verify the existence of unfavorable evidence. In our model, this assumption means that the court could verify the number of draws taken by the litigants but not the actual outcomes from the trials.

[10] That the potential for bias is not limited to the adversarial system but also exists in court-appointed systems is not unheard of. For example, Elliot (1989) notes that "the notion that a 'neutral, objective expert' exists on any subject, particularly ... on scientific issues, is not widely accepted."

liability lawsuit considered here, the quantity of interest $\theta$ is the proportion of defective items produced by the defendant's manufacturing process, and the court's damage award is a multiple $k>0$ of the estimated proportion of defectives. The court has several ways to draw inferences about $\theta$: it can obtain sample information from the production process, corresponding to the case where evidence is produced by a court-appointed expert, or, alternatively, it can rely on the information provided by the litigants to infer the value of $\theta$. The litigants observe whether the court has chosen to appoint an expert or not, but once they are called on to act they do not know whether the court is going to rely on the evidence produced by the plaintiff, by the defendant, by both, or only on its current state of information in deciding the award, and all these actions are equally likely to be chosen. At this point, plaintiff and defendant move simultaneously in presenting evidence to the court.[11]

We approach the problem of point estimation in the game using Bayesian decision theory. In this framework, the choice of an estimate can the thought of as a problem of decision making under uncertainty, where the actions correspond to the possible estimates.[12] In order to make a decision on just one value (or point estimate) of an uncertain quantity, the decision maker needs to determine which value is best. The choice of a "best estimate" or "best action" depends on the cost or loss to the decision maker from using an estimate of a parameter, say $\hat{\theta}$, that is not equal to the true parameter value $\theta$.[13] The function $L(\theta,\hat{\theta})$ that describes the consequences of basing a

[11] The simultaneity of moves here means that the game has imperfect information.

[12] The terms "estimates", "actions", and "decisions" are therefore used interchangeably throughout this discussion.

[13] While $\theta$ is referred to here as a parameter, given the Bayesian approach employed here it should be interpreted as a random variable. This is one of the aspects that distinguishes a classical from a Bayesian approach to the problem of point estimation. A Bayesian thinks of $\theta$ as a random variable, or uncertain quantity, and is willing to make probability statements concerning $\theta$. Prior and posterior distributions are probability distributions of $\theta$. The classical statistician, on the other hand, does not consider $\theta$ to be a random variable, but rather a fixed parameter, making it nonsense to talk of the probability of values of $\theta$ occurring within a classical framework.

decision on the point estimate $\hat{\theta}$, when $\theta$ is the true parameter value, is known as the *loss function,* and the Bayesian prescription to choose the point estimate which minimizes expected loss is a general operational principle consistent with the expected utility hypothesis most familiar to economists. The Bayesian point estimate is tailored to the particular loss function which is deemed appropriate and is an exact finite sample solution to the problem of point estimation. A slight confusion can arise, however, when we consider the problem of point estimation in an adversarial context. The problem in an adversarial context is that $\theta$ and $\hat{\theta}$ will seldom directly determine the ultimate loss for the plaintiff and for the defendant. In fact, in this context the ultimate loss depends on the court's award. Moreover, one characteristic of Bayesian decision theory is that it pertains to single agent problems. Some extensions, therefore, need to be considered for its application to multiagent environments.

Formally, in single decision theory an agent is to select a decision $\hat{\theta}$ from the space of all possible decisions $\varphi$. The Bayesian decision-maker wishes to choose his best course of action in the light of his prior knowledge, data which he gathers, and his losses for the various possible outcomes. The loss for the decision-maker for any such decision is assumed to depend on random variable $\theta$ with distribution $f(\theta)$. That is, the relationship among decisions, outcomes, and losses can be expressed by the function $L(\theta, \hat{\theta})$ representing the loss to the agent for decision $\hat{\theta}$ given outcome $\theta$. The agent acts to minimize his expected loss, $\int L(\theta, \hat{\theta}) df(\theta)$, by choice of his decision $\hat{\theta} \in \varphi$.

The distinguishing characteristic of multiagent environments is that the decision problem of any one agent or player cannot be considered independently of the decisions of others. To formalize this, suppose that there are $n$ agents or decision-makers. Each agent $i$ can make a decision $\hat{\theta}_i$ in some set of possible decisions $\varphi_i$. Then the loss to agent $i$ for decision $\hat{\theta}_i$ is assumed to depend on a random outcome $\theta$, as well as on the decisions of others, $\Theta_i \equiv (\hat{\theta}_1, \hat{\theta}_2, \ldots, \hat{\theta}_{i-1}, \hat{\theta}_{i+1}, \ldots, \hat{\theta}_n)$. These relationships may be described by a function $L_i$ where $L_i(\hat{\theta}_i, \Theta_i, \theta)$ is the loss to agent $i$. If the decision problem of any agent $i$ is to be well defined, then agent $i$ must be able to view his loss as a function of the random outcome $\theta$ and his own decision $\hat{\theta}_i$ only. The natural way to do this in the space of decisions is for agent $i$ to take the decisions $\Theta_i$ of others as fixed, independent of his own decision. But one would like to have the self-fulfilling property that the decisions which agent $i$ takes as given *are* in fact the decisions employed by the others.

This logic leads to the definition of a Nash equilibrium, which has this self-fulfilling property: a *Nash equilibrium* is a specification of a decision $\hat{\theta}_i^* \in \varphi_i$ for each agent $i \in \{1, 2, \ldots, n\}$ such that $\int L_i\left(\hat{\theta}_i^*, \Theta_i^*, \theta\right) df(\theta) \leq \int L_i\left(\hat{\theta}_i, \Theta_i^*, \theta\right) df(\theta)$ for all $\hat{\theta}_i \in \varphi_i$. Hence in a Nash equilibrium the decision $\hat{\theta}_i^*$ is optimal for each agent $i$ given the optimal decisions $\Theta_i^*$ of others. In many games, however, the concept of Nash equilibrium does not yield a unique prediction regarding agents' play. One refinement to the concept of Nash equilibrium that resolves the problem of multiple equilibria is the concept of subgame-perfect Nash equilibrium: a *subgame-perfect Nash equilibrium* is a specification of a decision $\hat{\theta}_i^* \in \varphi_i$ for each agent $i \in \{1, 2, \ldots, n\}$ such that (i) it is a Nash equilibrium for the entire game; and (ii) its relevant action rules are a Nash equilibrium for every subgame.[14] The concept of subgame-perfect Nash equilibrium is used to find the solutions for the litigation game developed here.

[14] For a textbook exposition of this and other refinements to the concept of Nash equilibrium see, for example, Kreps (1990).

*2.2. The court's decision problem*

It is assumed that the court acts so as to minimize the expected loss from basing its decision on a point estimate $\hat{\theta}$ when $\theta$ is the true proportion of defective items, bearing in mind the cost of sampling. Formally, let the court's loss function be given by

$$k(\hat{\theta}-\theta)^2 + c_c n_c \tag{1}$$

where $k$ is a positive constant, $n_c$ is the sample size, and $c_c$ is the cost of sampling. The first term in Eq. (1) corresponds to a quadratic loss function, whereby the loss associated with the estimation error (the difference between the estimate $\hat{\theta}$ and the true state of the world $\theta$) is proportional to the square of the error. Where the decision to be taken is the selection of a point estimate of a parameter, the following results are well known: using a squared-error loss function, the best point estimate is the posterior mean of the parameter, and the expected loss is then the posterior variance.[15]

Letting $f_c(\theta)$ denote the prior probability distribution for $\theta$, based on whatever evidence the court has, the expression for the court's expected loss is given by

---

[15] Formally, the decision maker seeks the value of $\hat{\theta}$ that minimizes expected posterior loss. The value of $\hat{\theta}$ that minimizes $L(\hat{\theta},\theta)$ is clearly $\hat{\theta}=\theta$. However, $\theta$ is not known. To overcome this problem, the decision-maker minimizes expected loss over all possible values of $\theta$ with the different values of $\theta$ being weighted by the posterior distribution $f(\theta|z)$ where $z$ stands for the sample outcome. Using a quadratic loss function, the expected posterior loss is given by $E_{\theta|z}(L) = \int k(\hat{\theta}-\theta)^2 f(\theta|z)\,d\theta$. Using differentiation under the integral sign, we have $d|d\hat{\theta}\{E_{\theta|z}\} = 2\int k(\hat{\theta}-\theta)\,f(\theta|z)\,d\theta$, which when equated to zero to obtain the minimizing value for $\hat{\theta}$ yields $\hat{\theta}\int f(\theta|z)\,d\theta = \int \theta f(\theta|z)\,d\theta$. From the properties of a proper density function, the integral on the left is unity, yielding $\hat{\theta} = \int \theta f(\theta|z)\,d\theta$. Thus, in a point estimation problem with a quadratic loss function of this form, the optimal point estimate is the mean of the distribution of $\theta$. It is only necessary to know the mean (not the entire distribution) in order to make a decision, and the decision-maker can act as though the mean is equal to the true value of $\theta$ with certainty; hence, the mean of the distribution is called a *certainty equivalent* in this situation. The basic result of this proof is that the expected squared deviation (or, the mean-square error) is smallest when calculated from the mean. This is the reason that the mean is the optimal estimate for a quadratic loss function, and it is also one of the reasons that the mean is considered by statisticians to be a "good" estimator. Estimation with a quadratic loss function is a Bayesian counterpart to the classical notion of efficient estimators. See, for example, Pratt, Raiffa, and Schlaifer (1995).

$$\int\int [k(\hat{\theta}-\theta)^2 + c_c n_c] f_c(\theta|z)\, d\theta f_c(z)\, dz \qquad (2)$$

where $z$ is the result of the sampling experiment,[16] $f_c(\theta|z) \propto f_c(z|\theta)\, f_c(\theta)$ is the posterior distribution for $\theta$ as obtained from Bayes' theorem, and $f_c(z) = \int f_c(z|\theta)\, f_c(\theta)\, d\theta$ is the marginal distribution for *z*.

It is assumed that the court's prior information over the unknown value of $\theta$ can be characterized by a Beta distribution with parameters $\alpha_1$ and $\alpha_2$, Beta($\alpha_1, \alpha_2$). The notation is $f_c(\theta) \propto \theta^{\alpha_1 - 1}(1-\theta)^{\alpha_1 - 1}$. The Beta distribution is the conjugate prior[17] to the binomial and is a function defined over the interval [0,1] with mean $\alpha_1 / (\alpha_1 + \alpha_2)$ and variance $\alpha_1\alpha_2 / (\alpha_1 + \alpha_2)^2(\alpha_1 + \alpha_2 + 1)$. It includes the uniform distribution $\{\alpha_1 = \alpha_2\}$ as a special case. The court uses the sampling results to update its prior beliefs about the value of $\theta$, and the estimator of $\theta$ is the mean of the posterior distribution. The revised (posterior) distribution for the court in the light of the data is then Beta with parameters $\alpha_1 + t,\ \alpha_2 + n - t$, where *t* denotes the number of defective items in a sample of size *n*, and the posterior mean and the posterior variance are given by $(\alpha_1 + t) / (\alpha_1 + \alpha_2 + n)$

[16] The results of sampling experiments are summarized by the sample size, *n*, and the sample number of defective items, *t*. Under the assumptions of a Bernoulli model, and where the uncertain quantity of interest is continuous, a sample statistic comprised of *n* and *t* is a *sufficient* statistic in that it contains all the information from the sample that is relevant with regard to the uncertainty about the quantity of interest. In this context, knowledge of the actual sequence of defective and nondefective items provides no more information about the quantity of interest (proportion of defective items) than does knowledge of *n* and *t*. In terms of Bayes' theorem, this means that knowledge of *n* and *t* is sufficient to determine the likelihoods, so that the posterior distribution of the proportion of defectives in the population given *n* and *t* is exactly the same as the posterior distribution of the proportion of defectives in the population given the entire sequence of results.

[17] When observations have a binomial distribution, Beta prior distributions for $\theta$ are said to be *conjugate* because the posterior distribution of $\theta$ is also in the Beta family.

and $(\alpha_1 + t)(\alpha_2 + n - t) / (\alpha_1 + \alpha_2 + n)^2 (\alpha_1 + \alpha_2 + n + 1)$, respectively. Additionally, the court's marginal predictive distribution for $t$ is beta-binomial:[18]

$$f_c(t) = [\Gamma(\alpha_1 + t)\Gamma(\alpha_2 + n - t)\Gamma(\alpha_1 + \alpha_2)n!] / [\Gamma(\alpha_1)\Gamma(\alpha_2)\Gamma(\alpha_1 + \alpha_2 + n)t!(n-t)!] \quad (3)$$

for $t=0,1, \ldots ,n$, where $\Gamma$ represents the Gamma function.[19]

Where the court decides not to sample, $c_c$ in Eqs. (1) and (2) equals zero and $z$ in Eq. (2) is the evidence provided by the litigants. The court uses such evidence to update its prior beliefs about the value of $\theta$, and again the estimator of $\theta$ is the mean of the posterior distribution. This updating can be made based on the evidence provided by both litigants or on the evidence provided by just one of the litigants.

### *2.3. The litigants' decision problem*

In the model, the population fraction of defective items is represented by the mean of a binomial distribution, and the litigants present evidence to the court drawn from this

[18] From a general statistical perspective, the analysis carried out here falls under the heading of *preposterior analysis*. In this context, the term preposterior analysis refers to the decision-maker's attempt to look forward, *before* he gathers the data, to the situation in which he will find himself after the data are gathered. The purpose of looking forward is to enable him to plan his data-gathering procedure efficiently. Since there is a cost involved in sampling, the decision-maker wishes to determine the worth to him of sample information so that he can decide whether or not to take a sample, that is, whether sample information is expected to be useful enough to justify its cost. This type of decision is called a *preposterior decision* because it involves the *potential* posterior distributions following the *proposed* sample. Notice that such sample has not been observed yet; it is just being contemplated. Before taking the sample, the decision-maker does not know the actual sample outcome, but he can make some probabilistic statements about possible results. Probability distributions for future sample outcomes are called *predictive distributions*, and where relevant these are the distributions used here even if the term "predictive" is omitted.

[19] Formally, $\Gamma(\alpha_1) = \int_0^\infty \theta^{\alpha_1 - 1} e^{-\theta} d\theta,\ \alpha_1 \succ 0.$ If $\alpha_1$ is an integer, then $\Gamma(\alpha_1) = (\alpha_1 - 1)!$ where ! denotes the factorial function, and $e$ is the base of the Naperian system.

distribution[20]. It is assumed that they produce evidence so as to minimize their respective expected losses from trial. In particular, the plaintiff seeks to minimize the difference between the true level of damages and the court's award (the transfer payment from the defendant to the plaintiff). Since the plaintiff bears the cost of producing evidence, his loss function also depends on the sample size. Formally, supposing linearity in both $\theta$, the damage award, and the sample size chosen, the plaintiff's loss function is given by

$$k(\theta - \hat{\theta}) + c_p n_p \tag{4}$$

where $k$, $\theta, \hat{\theta}$ are defined as above, and $n_p$ is the sample size taken by the plaintiff, and $c_p$ denotes the plaintiff's sampling costs. Assuming that the plaintiff knows the true level of damages the only uncertainty concerns the court's estimate of damages. In this case, plaintiff's expected loss is given by

$$\int [k(\theta - \hat{\theta}) + c_p n_p]\, f_p(\hat{\theta}|x, y)\, d\hat{\theta} \tag{5}$$

where $x$ and $y$ denote the evidence produced by the plaintiff and defendant, respectively, and $f_p(\hat{\theta}|x, y)$ is the plaintiff's assessment of the court's estimate of damages on receipt of such evidence.

[20] It is, therefore, assumed that the size of the relevant samples are fixed and that the number of defective items is a random variable. In sampling from a Bernoulli process (a dichotomous process since each observation takes one of only two possible values) it is also possible to sample with a fixed number of defective items (sample until a certain fixed number of defective items are obtained) in which case the sample size is a random variable. The former sampling procedure is called *Binomial sampling*, while the latter is called *Pascal sampling* since the distribution of the sample size is a Pascal distribution. However, this assumption is irrelevant to the application of Bayes' theorem, since the two distributions differ only with respect to combinatorial terms and these cancel out when Bayes' theorem is used. Thus, when sampling from a Bernoulli process it is not necessary to know whether the sampling is done with fixed sample size or with fixed number of defectives to determine the posterior distribution. The procedure used to tell the decision-maker when to stop sampling is called a stopping rule, and if the stopping rule has no effect on the posterior distribution, then it is said to be *noninformative*. The two stopping rules discussed here (sample until you have a certain fixed number of trials, and sample until you have a certain number of defectives) are both noninformative.

In the case where the plaintiff is uncertain about the actual extent of the injury, plaintiff's expected loss is given by

$$\int\int\int [k(\theta - \hat{\theta}) + c_p n_p]\, f_p(\theta|x)\ d\theta f_p(\hat{\theta}|x, y)\ d\hat{\theta} f_p(x)\ dx \tag{6}$$

where $f_p(\theta|x) \propto f_p(x|\theta) f_p(\theta)$ is the plaintiff's posterior distribution for $\theta$, $f_p(\theta)$ is the prior distribution, $f_p(\hat{\theta}|x, y)$ is the plaintiff's assessment of the court's estimate of damages on receipt of evidence *x* and *y* provided by the plaintiff and the defendant, and $f_p(x)$ is the marginal distribution for *x*. Assuming that the plaintiff's prior beliefs about the extent of injury can be characterized by a Beta distribution with parameters $\beta_1$ and $\beta_2$, Beta($\beta_1, \beta_2$), then $f_p(\theta) \propto \theta^{\beta_1 - 1}(1-\theta)^{\beta_2 - 1}$, and $f_p(x)$ is beta-binomial.

The defendant's behavior is modeled as symmetric to plaintiff's behavior. In particular, the defendant seeks to minimize the difference between the court's damage award to the plaintiff, and the true level of damages inflicted on the plaintiff. In this context the level of damages can be thought of as the benefit that the defendant derived from not correcting the malfunction in defendant's manufacturing process that gave rise to plaintiff's injury. The assumption made here is that the benefit to the defendant equals the extent of injury caused to the plaintiff. Formally, the defendant's loss function is given by

$$k(\hat{\theta} - \theta) + c_d n_d \tag{7}$$

where $n_d$ is the sample size and $c_d$ denotes the defendant's sampling costs. In the case where the defendant knows the true level of damages, his expected loss is given by

$$\int [k(\hat{\theta}-\theta)+c_d n_d]\, f_d(\hat{\theta}|y,x)\; d\hat{\theta} \tag{8}$$

and by

$$\int\int\int [k(\hat{\theta}-\theta)+c_d n_d]\, f_d(\theta|y)\; d\theta f_d(\hat{\theta}|y,x)\; d\hat{\theta} f_d(y)\; dy \tag{9}$$

in the case where the defendant does not know the true level of damages. Assuming that the defendant's prior beliefs about the true level of damages, $f_d(\theta)$, can be characterized by a Beta($\gamma_1, \gamma_2$) distribution, then $f_d(\theta) \propto \theta^{\gamma_1 - 1}(1-\theta)^{\gamma_2 - 1}$, and $f_d(y)$ is beta-binomial.

Note that the predictive distributions for the sampling experiments carried out by the court, the plaintiff, or the defendant, and their posterior distributions for $\theta$, need not to be equal since they may have different priors over the unknown value of $\theta$, reflecting the presence of asymmetric information. The system developed here is *simultaneous*, because the plaintiff's and defendant's decisions of how much and what evidence to produce depends on the court's strategy to infer the value of $\theta$, which, in turn, depends on the plaintiff's and defendant's decisions of how much and what evidence to produce. Additionally, the resulting expressions for the players' expected losses are not amenable to analytical methods of minimization. Thus, the behavioral properties of this model are best evaluated numerically.

## 3. Numerical implementation

This section considers several explicit examples that have been solved numerically.[21] The first set of examples refers to the case where the litigants are assumed to know the true value of damages. The second set of examples illustrates a similar game but in which the litigants are uncertain about the true value of damages. These two set of examples allow us to examine the effects of varying the informational endowments of the litigants on the court's equilibrium strategy for inferring the value of damages, and on the litigants' equilibrium reporting strategies.

In each set of examples, the players' expected losses were computed for $k$=100 and a constant marginal sampling cost of 0.1 for the three players in the game. Moreover, the players were allowed to choose a maximum sample size of two items. Lack of computing power precludes us from allowing a larger sample size; a maximum sample size of two items yields 6 possible actions for the court (sample 1 item, sample 2 items, rely only on priors, rely only on evidence reported by the defendant, rely only on evidence reported by the plaintiff, rely on evidence produced by both litigants), and 5 possible actions for each of the litigants (sample 1 item and report 0 defectives, sample 1 item and report 1 defective, sample 2 items and report 0 defectives, sample 2 items and report 1 defective, sample 2 items and report 2 defectives)[22] amounting to 150 strategies available for the court, and 100 strategies available for each of the litigants. Despite the small sample size, this numerical exercise allows us to readily examine the wisdom that the defendant reports 0 defectives regardless of the sample size chosen, and

[21] A machine-readable copy of the QuickBASIC code used to solve the game is available from the author for anybody wishing to replicate and/or extend the results presented here.
[22] Keeping with the numerical evaluation of Froeb and Kobayaschi (1996) and Farmer and Pecorino (2000)' models, the choice of not producing evidence is not open to the litigants in the numerical exercise performed here, which allows for a direct comparison of the equilibrium results from the models.

that the plaintiff reports as much defectives as possible given the number of sampled items.

*3.1. The game with informed plaintiff and informed defendant*

The numerical behavior of this model is investigated for different possible values of $\theta$, and for different prior beliefs held by the court over the unknown value of $\theta$. In particular, nine different scenarios are constructed corresponding to different combinations of three true $\theta$ values, and three possible sets of prior beliefs ($\breve{\theta}$) held by the court over the value of $\theta$. Table 1 displays the scenarios under analysis in this numerical exercise, as well as the court's final estimate of $\theta$ (the values under $\hat{\theta}$).

In the first scenario, corresponding to the first row of numbers in the Table, the court's prior information is given by $\breve{\theta}$=.2 reflecting the view that 20% of the items produced by the defendant are defective.[23] In the second scenario the court has a uniform prior over the unknown $\theta$, and in the third scenario the court holds the view that 80% of the items are defective. In these three scenarios the true proportion of defective items equals 20%. The remaining scenarios differ from these with respect to the true value of $\theta$. In the next three scenarios the true value of $\theta$ is assumed to be 50%; it is assumed to be 80% for the scenarios described in the last three rows. Table 1 also displays the equilibrium strategy for each player, where $n_p$ ($n_d$) stands for sample size and $t_p$ ($t_d$) stands for the number of defective items reported by the plaintiff (defendant).

Table 1 shows that, for these parameter values, equilibrium play never involves the court's sampling strategy. This result sits well with the observation that although under

[23] This is given by a Beta distribution with parameters $\alpha_1 = 2,\ \alpha_2 = 8$, for example.

the U.S Federal rules courts may appoint expert witnesses, this power has been exercised very infrequently.[24] Examination of the results also reveals that in equilibrium the court relies on the party that provides evidence that tends to support the court's prior beliefs concerning the value of $\theta$. The possibility of such behavior in actual civil cases is not unheard of, and in fact the law permits jurors to disregard evidence which they are skeptical of.[25]

Table 1. Numerical examples

| $\theta$ | $\breve{\theta}$ | Equilibrium Strategies | | | | | $\hat{\theta}$ |
|---|---|---|---|---|---|---|---|
| | | Plaintiff | | Defendant | | Court | |
| | | $n_p$ | $t_p$ | $n_d$ | $t_d$ | | |
| .2 | .20 | 1 | 1 | 2 | 0 | *defendant* | .17 |
| | .50 | 2 | 2 | 2 | 0 | *both* | .50 |
| | .80 | 2 | 2 | 1 | 0 | *plaintiff* | .83 |
| .5 | .20 | 1 | 1 | 2 | 0 | *defendant* | .17 |
| | .50 | 2 | 2 | 2 | 0 | *both* | .50 |
| | .80 | 2 | 2 | 1 | 0 | *plaintiff* | .83 |
| .8 | .20 | 1 | 1 | 2 | 0 | *defendant* | .17 |
| | .50 | 2 | 2 | 2 | 0 | *both* | .50 |
| | .80 | 2 | 2 | 1 | 0 | *plaintiff* | .83 |

[24] Many reasons have been advanced in the literature for the sparing use of court-appointed experts. One popular reason is that juries may accord undue weight to the opinion of the court's expert simply because the expert is associated with the court. However, recent empirical studies tend to show that jurors appear to accord less attention to the testimony of court-appointed experts than they do to that of partisan experts. See, for example, Burk (1993), and Johnston (1988) for a discussion of this and related objections to the use of court-appointed experts.

[25] Shuman et al. (1994) refer to a case in the city of New York where "... after a week had been consumed hearing expert testimony upon a subject concerning which an equal number of doctors had testified exactly opposite to each other, and all with equal positiveness, the judge told the jury to put all the expert testimony out of their minds, and to pay no attention to it". Another example where the law permits the jury to disregard evidence, when the jury considers that evidence is not trustworthy, is provided by Jonhston (1988). She reports on a sample jury instruction charging the jury that "The rules of evidence provide that if scientific, technical, or other specialized knowledge might assist the jury in understanding the evidence or in determining a fact in issue, a witness qualified as an expert by knowledge, experience, training, or education, may testify and state his opinion concerning such matters. .... You should consider each expert opinion received in evidence in this case and *give it such weight as you may think it deserves*. If you should decide that the opinion of an expert witness is not based upon sufficient education and experience, or if you should conclude that the reasons given in support of the opinion are not sound, or that the opinion is outweighed by other evidence, *then you may disregard the opinion entirely*." (emphasis added).

Equilibrium play also reveals that litigants' evidence production and reporting strategies are driven by their knowledge of the court's potential strategic behavior and prior beliefs, rather than by their knowledge of the true distribution of damages. Analysis of the scenarios where $\breve{\theta}=.2$ shows that, regardless of the known value of true damages, the defendant produces evidence so as to corroborate the court's view that the true level of damages is low. The plaintiff, on the other hand, produces the least amount of evidence possible, reflecting the point that it is not worthwhile for the plaintiff to attempt to convince the court of the soundness of plaintiff's views. These patterns of costly evidence production emerging as a consequence of equilibrium play are reversed for the plaintiff and defendant when it is common knowledge that the court's prior beliefs are such that the true value of damages is high ($\breve{\theta}=.8$). If it is common knowledge that the court has uniform or neutral priors over the unknown value of damages ($\breve{\theta}=.5$), each party produces as much evidence as possible and evidence that exactly counterbalances the evidence produced by the opposing party. These findings suggest that the result from Farmer and Pecorino, that the party disfavored by the objective facts of the case (the true $\theta$) but favored by the jury spends more than their opponent at trial under the English indemnity rule, can be extended to settings where the American rule is in place.

Moreover, the results reported in Table 1 confirm the conventional belief that litigants only report information favorable to their own case. However, contrary to the findings in Milgrom and Roberts' and Froeb and Kobayaschi' models, but in line with those of Farmer and Pecorino, the results do not support the claim that two adversaries vigorously advocating their respective positions will produce the truth or full disclosure of information. In fact, a comparison between the values for $\theta$, $\breve{\theta}$, and $\hat{\theta}$ in Table 1 shows that the endogenous information-gathering and reporting decisions of the plaintiff and defendant reinforce the initial jury bias. For the scenarios where the true value of $\theta$ favors the plaintiff, a jury bias in favor of the plaintiff causes $\hat{\theta}$ to move past $\theta$ implying that the litigants' decisions of how much and what evidence to produce magnifies the initial jury bias ($\hat{\theta} > \breve{\theta} = \theta$). Likewise, when the true facts of the case favor the defendant and the jury bias favors the defendant, the evidence produced by the litigants causes $\hat{\theta}$ to move further from $\theta$ ($\hat{\theta} < \breve{\theta} = \theta$). Taken together, our findings and those of Farmer and Pecorino, suggest that the result from Milgrom and Roberts and Froeb and Kobayaschi, that competition among adversaries leads to the emergence of "truth", is highly sensitive to assumptions concerning the decision-maker's strategy to interpret any information reported to him.

*3.2. The game with uninformed plaintiff and uninformed defendant*

Now the informational structure of the game is modified to allow for a less well-informed plaintiff and defendant about the true damage. The numerical behavior of this model is investigated for three possible prior beliefs ($\breve{\theta}$) held by the court, the plaintiff, and the defendant over the unknown value of $\theta$. The first three columns of Table 2 display the particular parameter values for the priors under consideration.[26] For ease of exposition we will refer to the players as "type 1" players if their prior information is assumed to be characterized by a Beta distribution with parameters $\alpha_1$ and $\alpha_2$ such that the prior mean is $\breve{\theta}$=.2. Thus, if this particular distribution represents the court's prior belief over the value of $\theta$, we will refer to the court as a "type C1" court. The court will

[26] Note that these information structures are states, not strategies.

be referred to as a "type C2" and "type C3" court if its Beta priors are summarized by $\breve{\theta}=.5$ and $\breve{\theta}=.8$, respectively. Similar reasoning applies to the other players in the game.

Table 2. Numerical examples

| $\breve{\theta}$ Court | $\breve{\theta}$ Plaintiff | $\breve{\theta}$ Defendant | Equilibrium Strategies: Plaintiff $n_p$ | Plaintiff $t_p$ | Defendant $n_d$ | Defendant $t_d$ | Court | $\hat{\theta}$ |
|---|---|---|---|---|---|---|---|---|
| .20 | .20 | .20 | | | | | *appoint(2)* | .20 |
| | | .50 | | | | | *appoint(2)* | .20 |
| | | .80 | | | | | *appoint(2)* | .20 |
| | .50 | .20 | 2 | 0 | 1 | 0 | *both* | .15 |
| | | .50 | | | | | *appoint(2)* | .20 |
| | | .80 | | | | | *appoint(2)* | .20 |
| | .80 | .20 | 2 | 0 | 1 | 0 | *both* | .15 |
| | | | 2 | 0 | 2 | 1 | *plaintiff* | .17 |
| | | .50 | 2 | 0 | 1 | 1 | *plaintiff* | .17 |
| | | .80 | 2 | 0 | 1 | 1 | *plaintiff* | .17 |
| .50 | .20 | .20 | 1 | 0 | 2 | 2 | *both* | .54 |
| | | .50 | 1 | 0 | 1 | 1 | *both* | .50 |
| | | .80 | 1 | 0 | 1 | 1 | *both* | .50 |
| | .50 | .20 | 1 | 0 | 2 | 2 | *both* | .54 |
| | | .50 | 1 | 0 | 1 | 1 | *both* | .50 |
| | | .80 | 1 | 0 | 1 | 1 | *both* | .50 |
| | .80 | .20 | 2 | 0 | 2 | 2 | *both* | .50 |
| | | .50 | 2 | 0 | 1 | 1 | *both* | .46 |
| | | .80 | 2 | 0 | 1 | 1 | *both* | .46 |
| .80 | .20 | .20 | 1 | 0 | 2 | 2 | *defendant* | .83 |
| | | .50 | 1 | 0 | 2 | 2 | *defendant* | .83 |
| | | .80 | | | | | *appoint(2)* | .80 |
| | .50 | .20 | 1 | 0 | 2 | 2 | *defendant* | .83 |
| | | .50 | 1 | 0 | 2 | 2 | *defendant* | .83 |
| | | .80 | | | | | *appoint(2)* | .80 |
| | .80 | .20 | 1 | 1 | 2 | 2 | *both* | .85 |
| | | | 2 | 1 | 2 | 2 | *defendant* | .83 |
| | | .50 | 1 | 1 | 2 | 2 | *both* | .85 |
| | | | 2 | 1 | 2 | 2 | *defendant* | .83 |
| | | .80 | 2 | 1 [1.00] | 1 | 1 [.91] | *both[.03]* | .81 |
| | | | | | 2 | 0 [.06] | *defendant[.97]* | |
| | | | | | 2 | 2 [.03] | | |

Table 2 also displays the equilibrium strategy for each player in twenty-seven scenarios corresponding to different combinations of players' prior beliefs over the unknown value of $\theta$. Notice that for some of the scenarios, play of the game yielded two subgame-perfect Nash equilibria in pure strategies. This is indicated in the relevant cells of the Table by a brace. Additionally, play of the game under the last scenario in the Table yielded a mixed-strategy equilibrium. The probabilities with which players play their equilibrium strategies are reported in square brackets. Moreover, equilibrium play for some of the scenarios involves the court's sampling strategy.[27] In that case, defendant and plaintiff are not called on to act and their off-equilibrium strategies are omitted. The court's optimal sample size is the value reported in round brackets.

The results displayed in Table 2 reveal that, in equilibrium, a type C1 court never relies on the information provided by the defendant in order to determine the amount of damages to be awarded to the plaintiff. This result is opposed to that found for the game with no uncertainty from the litigants' side about the true value of $\theta$, and is a consequence of two forces. The first is the defendant's tendency to produce the least amount of evidence possible, and evidence that tends to reflect his own prior beliefs about the true value of $\theta$. The second is the plaintiff's tendency to produce more evidence that corroborates court's prior opinion about the true value of $\theta$. These patterns of equilibrium behavior are reversed when it is common knowledge that the court's prior beliefs are such that the true value of $\theta$ is high (type C3). Indeed, for the scenarios reported in the last panel of Table 2, corresponding to a type C3 court, the court never relies on information provided by the plaintiff to infer the value of $\theta$. Being favored by the court's prior, the plaintiff tends to produce the least amount of evidence

[27] Although the appointment of court experts is rare, this is not to say that such power is never exercised. See Johnston (1988) for several examples where judges have appointed experts of their own choosing without the consent of either party.

possible, and evidence that reflects his own prior information concerning the value of $\theta$. The defendant, on the other hand, tends to produce evidence that supports the court's view of $\theta$.

Equilibrium play also reveals that the court's optimal strategy for the scenarios where it has uniform priors over $\theta$ is to rely on the information provided by both parties in determining the award. The litigants display an equilibrium behavior similar to their behavior in the scenarios where the court has nonuniform priors over $\theta$. Table 2 demonstrates that when the court's priors are unfavorable to the litigants (the cases where plaintiff is type P3 and defendant is type D1) the litigants produce more evidence, and evidence that is damaging to their own interests, than in scenarios where litigants are favored by court's prior beliefs over $\theta$ (the cases where plaintiff is type P1 or P2, and defendant is type D2 or D3).

Taken together, and consistent with the findings in Froeb and Kobayaschi's model, these results reveal a tendency of the parties to "free ride" on the prior beliefs of the court. When the court has prior beliefs that favor one party, that party produces less evidence. Thus, although the patterns of costly evidence production emerging out of Froeb and Kobayaschi's model do not hold in a model where the litigants are assumed to know the true value of $\theta$, they do arise in a model where litigants' are uncertain about that quantity.

Moreover, the results show that strategic behavior by a decision-maker can induce interested parties to produce evidence that is damaging to their interests. The parties do so to avoid a potentially more unfavorable inference by the strategic decision maker. Thus, reporting unfavorable information is a best-response in a game-theoretic sense because it avoids the court dismissing the information reported by one party and relying only on the information reported by the opposing party.[28] Finally, the values found for $\hat{\theta}$ in Table 2 are generally consistent with those in Table 1, showing that the endogenous information-gathering and reporting decisions of the plaintiff and defendant reinforce the initial jury bias.

## 4. Conclusion

The models developed and analyzed here are designed to tell us something about litigants' behavior at trial and the court's approach to uncover the truth underlying a dispute. As examples these models can only establish possibilities, not general results. Nonetheless, some conclusions can be drawn about the validity of commonly accepted hypotheses guiding the debate over the presentation of evidence in the courtroom, and the efficacy of the trial system as a truth-seeking enterprise. In particular, we find that the hypothesis that litigants only report information favorable to their own case is in some respects wider and in other respects narrower than would appear to be commonly thought. Our results suggest that the assumption that litigants only report the most favorable information to the courts can be extended to situations in which the decision-maker acts strategically. This conclusion, however, is sensitive to assumptions concerning the informational endowments of the litigants. Indeed, it only applies to situations where litigants are assumed to know the true value of the parameter under dispute with certainty. In situations where this assumption does not hold, we find that equilibrium play leads each interested party to reveal information that is damaging to its interests to gain in credibility.

[28] This result fits well with Tullock (1987: p.99)'s argument that parties to a lawsuit may report evidence that is apparently against them because the truth is even more likely to hurt them. More closely related to the analysis performed here is Kaplow and Shavell (1989)'s note that "Whether some evidence is favorable may depend on what other evidence is presented…Note that unfavorable evidence offered to preempt its presentation by an adversary can be seen as favorable because *the relevant question is the effect of presenting it relative to that of withholding it*" (note 25, section III.A) (emphasis added).

In addition, the results of the illustrative model of litigation analyzed here run counter to the wisdom that competition among litigants forces them to reveal all relevant information. Rather, we find that litigants' reporting strategies tend to be driven by their knowledge of the court's potential strategic behavior and prior beliefs, rather than by their knowledge of the true value of the parameter under dispute. Finally, and in line with the findings of Farmer and Pecorino, the results indicate that the equilibrium information-gathering and reporting strategies of litigants exacerbate the effects of decision-makers' bias on trial outcomes. Thus, the result from Milgrom and Roberts, and Froeb and Kobayaschi, that competition among adversaries elicits all relevant information leading to accurate decision-making, seems to be highly sensitive to (i) assumptions concerning the decision-maker's strategy to interpret any information reported to him, (ii) the interested parties' knowledge of how the decision maker infers the value of the parameter under dispute, and (iii) assumptions concerning the interested parties' reporting strategies. We find that many of these assumptions do not arise naturally, in the sense that they are not necessarily part of an equilibrium of a more generally specified game where the court's decision to weigh evidence and litigants' reporting strategies are endogenously determined.

## References


Burk, D.L. (1993), "When Scientists act like Lawyers: the problem of adversary science", *Jurimetrics Journal*, 33, 363-376.

Cecil, J.S., Hans, V.P. and Wiggins, E.C. (1991), "Citizen comprehension of difficult issues: lessons from civil jury trials", *American University Law Review*, 40, 727-774.

Elliot, E.D. (1989), "Toward incentive-based procedure: three approaches for regulating scientific evidence", *Boston University Law Review*, 69, 487-487.

Farmer, A. and Pecorino, P. (2000), "Does jury bias matter?", *International Review of Law and Economics*, 20, 315-328.

Froeb, L.M. and Kobayashi, B.H. (1996), "Naive, Biased, yet Bayesian: can juries interpret selectively produced evidence?", *Journal of Law, Economics, and Organization*, 12, 257-276.

Greene, E., Goodman, J. and Loftus, E. (1991), "Jurors' attitudes aboutcivil litigation and the size of damage awards", *American University Law Review*, 40, 805-820.

Johnston, P.L. (1988), "Court Appointed Scientific Expert Witnesses: Unfettering Expertise", *High Technology Law Journal*, 2, 249-280.

Kaplow, K. and Shavell, S. (1989), "Legal advice about information to present in litigation: its effects and social desirability", *Harvard Law Review*, 102, 565-615.

Kreps, D.M. (1990), *A course in Microeconomic Theory*, New Jersey: Princeton University Press.

Milgrom, P. and Roberts, J. (1986), "Relying on the information of interested parties", *Rand Journal of Economics*, 17, 18-32.

Pratt, J.W., Raiffa, H. and Schlaifer, R. (1995), *Introduction to Statistical Decision Theory*, Cambridge: MIT.

Rubinfeld, D.L. (1984), "On determining the Optimal Magnitude and Length of Liability in Torts", *Journal of Legal Studies*, 13, 551-563.

Sobel, J. (1985), "A Theory of Credibility", *Review of Economic Studies*, 52, 557-574.

Shuman, D.W., Whitaker, E. and Champagne, A. (1994), "An empirical examination of the use of expert witnesses in the courts - Part II: a three city study", *Jurimetrics Journal*, 34, 193-208.

Thornton, R. and Ward, J. (1999), "The Economist in Tort Litigation", *Journal of Economic Perspectives*, 13, 101-112.

Tullock, G. (1987), *The logic of the law*, Fairfax, Virginia: George Mason University Press.

Vidmar, N. and Rice, J. (1993), "Assessments of noneconomic damage awards in medical negligence: a comparison of jurors with legal professionals", *Iowa Law Review*, 78, 883-911.

Viscusi, W.K. (1988), "Pain and suffering in product liability cases: systematic compensation or capricious awards?", *International Review of Law and Economics*, 8, 203-220.

Ward, K.M. and Duffield, J.W.(eds.)(1992), *Natural Resource Damages: Law and Economics,* New York: John Wiley & Sons.