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# Better that ten guilty persons escape: punishment costs explain the standard of evidence

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**Abstract** It is generally agreed that the conviction of an innocent person (type-I error) should be avoided even at the cost of allowing a certain number of acquittals of criminals (type-II error). The high *standard of evidence* that is usually required in criminal procedure reflects this principle. Conversely, the established model of optimal deterrence that follows the seminal work of Becker (1968) shows that the two types of error are equally detrimental in terms of deterrence and thus it prescribes the minimization of the sum of errors with no primacy given to type-I errors over type-II errors. This paper explains that when the *costs of punishment* are positive, and guilty individuals are, on average, more likely to be found guilty than innocent ones, wrongful convictions are more socially costly than wrongful acquittals. This justifies the bias against wrongful convictions without resorting to any *ad hoc* assumption about the relative weight of the two errors.

**Keywords** Judicial errors · Type-I errors · Type-II errors · Optimal standard of evidence · Punishment costs

**JEL Classification** K14 · K41 · K42

> *Type-I errors in criminal cases involve additional cost because the cost of imprisonment is high. That cost is of course avoided when a guilty person is acquitted, though such an acquittal will reduce deterrence by reducing the probability of punishment for crime. But the asymmetric effect of the cost of imprisonment on convictions and acquittals means that it probably takes several erroneous acquittals to impose a social cost equal to that of an erroneous conviction*. Posner (2007: 648)

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## 1 Introduction

A cornerstone of criminal procedures in modern democracies is the robust protection granted to defendants through several procedural safeguards. King of these mechanisms is the high standard of evidence needed to reach a verdict of guilty. Imposing a heavy evidentiary burden on prosecutors protects the innocent from mistaken convictions (type-I errors) at the cost of allowing some—possibly many—guilty defendants to be set free (type-II errors). As Blackstone (1769: 352) puts it: *better that ten guilty persons escape, than that one innocent suffer*. Therefore, an inverse relation exists between type-I and type-II errors. However, the precise terms of this trade-off should be disentangled.

In an ideal world, society's goal is the containment of wrongful convictions and the high standard of evidence is thus instrumental in reaching this objective. But why does society struggle to "implement such an error trade-off"? And can we make economic sense of it?

The easy way to answer these questions is to assume that the two errors have different weights. Many models in the literature take this route and seek to establish the optimal standard of proof simply by assigning *ad hoc* weights to the two errors. These papers assume that type-I errors are more burdensome than type-II errors because of some ethical costs grounded in deontological reasoning: so that convicting the innocent is inherently bad and morally repugnant.

Some of these works dispense altogether with the consequences for deterrence of a high error ratio[1] and consider the optimization of the standard of evidence in terms of (i) expenditure by defendants (Rubinfeld and Sappington 1987; Yilankaya 2002); (ii) different fact-finding procedures (Davis 1994) and technologies (Sanchirico 1997); (iii) moral costs of different types of judicial error (Miceli 2009).

Other authors incorporate deterrence concerns and explain the high standard of evidence in terms of (iv) prosecutorial effort (Miceli 1990: 125) biased evidence selection (Schrag and Scotchmer 1994); (vi) parties' overcompliance (Craswell and Calfee 1986); (vii) optimal exercise of care by parties (Demougin and Fluet 2006) and precautionary activities (Mungan 2011); and (viii) marginal deterrence (Ognedal 2005).

The relationship between the standard of evidence and deterrence is especially important. Png (1986) shows that wrongful convictions are as inimical for deterrence as wrongful acquittals. This is because acquittals of guilty individuals make crime more attractive by diluting deterrence, but also convictions of innocent persons make crime more convenient by lowering the relative benefits of remaining honest. For the purposes of our discussion it is noteworthy that the high standard of evidence of criminal proceedings cannot easily be reconciled with the Png result, which instead prescribes the minimization of the sum of errors.[2]

So far the puzzle seems to have been the following: either scholars stuck with the model of optimal deterrence which seemed unable to explain the observed high standards of evidence, or they added some *ad hoc* assumptions to the model to adjust for the reality. With the present work we instead show that only deterrence and purely economic costs can explain the high standard of evidence without leaving the parsimonious utilitarian setting of the standard model of optimal deterrence *à la* Polinsky and Shavell (2009). In particular, we do not resort to any restrictive ethical assumption to justify the different costs of the

[1]On the difference between the error ratio and the standard of evidence, see Allen and Pardo (2007), Allen and Laudan (2008).

[2]The Png result has been questioned recently by Lando (2006) although Lando's point has in turn been criticized by Garoupa and Rizzolli (2012, forthcoming).

two types of errors. The paper shows that although the two errors cost the same in terms of foregone deterrence (Png's result), they have an opposite impact on the costs of punishment.

Four articles are related to ours because they combine standard of evidence, costs of punishment and deterrence. First Kaplow and Shavell (1994), who develop a model on accuracy of adjudication, and Kaplow (1994), where the implications of the previous model for the standard of evidence are introduced discursively. Along our lines the latter paper states that when sanctions are costly, the achievement of optimality requires an appropriate mix that balances fact-finding accuracy, evidentiary standards and the rate at which criminal activity is detected and punished. We provide analytical results that support most of Kaplow's conclusions, but depart from others. We further disentangle our results in relation to the problem of accuracy in Sect. 3.3.

Lando (2009) shows that the standard of evidence also depends on the costs of punishment. However, our work differs in a number of important ways. In fact, he still assigns different ethical weights to the two errors. Furthermore, he departs from Png (1986) by ruling out explicitly the possibility that type-I errors negatively impact deterrence. Finally, in his social costs function, he computes both the ethical costs and the costs of punishment of wrongful convictions.

Polinsky and Shavell (1992) distinguish two types of costs related to the system of punishment: (i) the *ex ante* fixed cost of maintaining the level of detection constant; and (ii) the *ex post* variable cost of punishment. They show that because of the latter, some underdeterrence is socially optimal.[3] We also reach this conclusion as we point out that the costs of punishment imply an optimal standard of evidence more stringent than the one that maximizes deterrence. However, while Polinsky and Shavell focus on the detection probability at the police level and in fact ignore type-I errors, we focus on the trade-off of errors at the trial court level.

The paper is organized as follows: Sect. 2 extends a standard model of deterrence. We will show that imposing a heavy evidentiary burden on the state's prosecutors can be justified within a standard model. Section 3 discusses some possible extensions of the model, while Sect. 4 derives some policy implications and concludes.

## 2 The model

Ideally judicial truth and factual truth should coincide. In reality they do not, and when judicial guilt is established in presence of factual innocence a type-I error occurs, while if judicial innocence is established where there is factual guilt, then a type-II error happens.[4]

Even if known by someone, factual truth cannot be completely conveyed to the court. As a result, judicial truth becomes the generally accepted truth, and knowledge of both types of judicial error is scattered throughout society.

### 2.1 Evidence ($e$) and the standard of evidence ($\tilde{e}$)

When a defendant is accused of a crime, the aim of the legal process is to establish whether the defendant is *truly* guilty. The trial consists of a complex process wherein prosecutors and defendants present multiple and heterogeneous pieces of evidence that can be represented a

[3] In their 1984 work Polinsky and Shavell find that underdeterrence (or overdeterrence) may be the result of the use of imprisonment as a sanction. But this is a different matter.

[4] On the definition, the determinants, and the probabilities of judicial errors see Tullock (1980: 24, 1994).

measure taking a positive sign when it is consistent with the defendant's guilt and a negative sign when it supports the defendant's innocence. The difference between incriminating and exculpatory evidence is validated, distilled and crystallized into a unique measure of net incriminating evidence $e$. If $e$ overcomes a certain threshold $\tilde{e}$ that is determined by the policy maker and represents the *standard of evidence*, then the defendant is judged guilty and punished. For this reason the adjudicative body is usually modeled as a publicly spirited bureaucrat who acts as an impartial and unbiased referee and, in our model, may hand down verdicts of guilty or not guilty only by comparing the status quo evidentiary standard with the testimony heard and exhibits entered into the record at trial.

In the present work we ignore how $e$ is produced and we simply model it as an exogenous variable (we briefly discuss the production of $e$ in Sect. 3.2). Instead we focus on the policy problem of defining the optimal standard of evidence $\tilde{e}$: the key variable that is determined endogenously herein. Given that there are certain punishment costs associated with conviction, we focus on how $\tilde{e}$ should vary in order to minimize total costs.

### 2.2 Evidence *vs* truth: the first-order stochastic dominance

Incriminating evidence depends on several case-specific factors such as the personal abilities of counsel representing the adversarial parties (the defendant lawyer's skill in refuting allegations of guilt and the prosecutor's ability to establish the defendant's culpability) and other factual circumstances; it also depends on whether or not the defendant actually committed the crime. We can thus model the amount of net incriminating evidence $e$ observed by the court as a random variable. It is distributed according to two generic distributions conditional on the defendant being actually guilty or innocent.

Thus, let $I(e)$ be the positive, continuous and differentiable cumulative function of $e$ for innocent parties and let $G(e)$ be the positive, continuous and differentiable cumulative function of $e$ for guilty ones. No restrictive assumption regarding the shapes of these distributions is made. However, in the model it is reasonable to assume that $G(e) \leq I(e)$ for all $e$, with strict inequality at some $e$, that is to say that $G(e)$ has first-order stochastic dominance over (f.o.s.d.) $I(e)$. The two cumulative functions are depicted in Fig. 1.

F.o.s.d. implies that, *on average*, the amount of net incriminating evidence that is collected against a factually guilty person is larger than the amount collected against an innocent one.[5] If it were not the case, then the whole criminal procedure would be pointless and there would be no reason to analyze uninformative evidence.

### 2.3 Judicial errors and the standard of evidence

The court may mistakenly decide for a conviction when it observes $e > \tilde{e}$ and the defendant is in fact innocent. Therefore the probability of convicting an innocent person (type-I error) is $1 - I(\tilde{e})$. Conversely, a mistaken acquittal occurs when $e \leq \tilde{e}$ and the defendant is factually guilty (type-II error). The probability of committing a type-II error is $G(\tilde{e})$.

In Fig. 1 note that when the *standard of evidence* increases, changing, for instance, from the level $\tilde{e}_{Low}$ to the level $\tilde{e}_{High}$, the probability of conviction decreases for both guilty and innocent individuals as $1 - I(\tilde{e}_{High}) < 1 - I(\tilde{e}_{Low})$ and $1 - G(\tilde{e}_{High}) < 1 - G(\tilde{e}_{Low})$.

[5] In the literature, the assumption of f.o.s.d. has also been used by Miceli (1990, 2009: 125) and Feess and Wohlschlegel (2009).

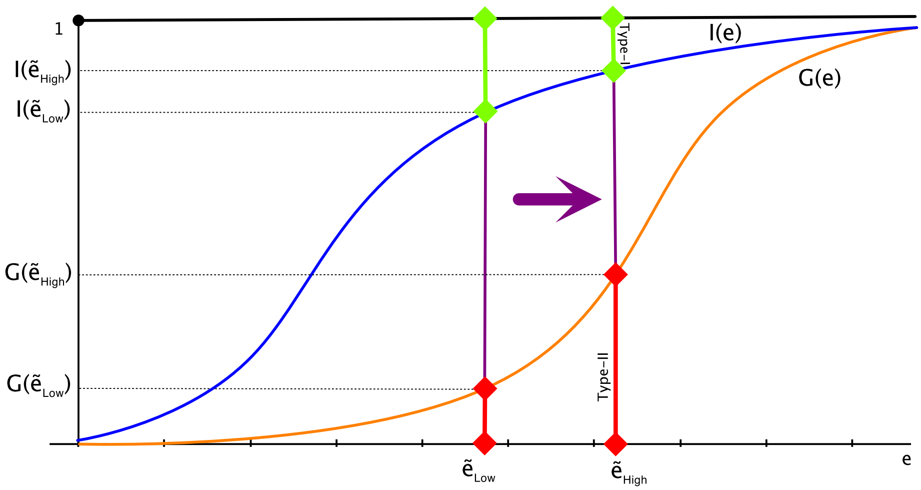


**Fig. 1** Cumulative distributions of the net incriminating evidence $e$, for guilty and innocent persons

**Lemma 1** *The continuity and differentiability of $I(e)$ and $G(e)$ as well as the assumption of f.o.s.d. are sufficient conditions to sustain that there must exist an $0 < e < \infty$ for which $i(e) = g(e)$.*

Proof is provided in the Appendix A.

Let us name the level of $e$ for which $i(e) = g(e)$ as $\tilde{e}_{\min}$. Note that

$$\begin{cases} \text{for } e \le \tilde{e}_{\min} & i(e) \ge g(e) \\ \text{for } e > \tilde{e}_{\min} & i(e) < g(e) \end{cases} \tag{1}$$

The threshold $\tilde{e}_{\min}$ is relevant for our analysis because the inequalities above tell us that wrongful convictions decrease faster than correct convictions to the left of $\tilde{e}_{\min}$ while they decrease more slowly to the right. This implies that the sum of the two errors decreases until $\tilde{e}_{\min}$ and grows again thereafter. The sum of errors is minimized when the standard of evidence $\tilde{e} \equiv \tilde{e}_{\min}$.

Note that in this setting, the standard of evidence is the only policy variable. Moreover the standard of evidence $\tilde{e}$ can be set at different levels at no cost. This analysis keeps accuracy constant for every given level of evidence and forensic technology. In other words, the shapes of the functions $I(e)$ and $G(e)$ remain unchanged. Only the level of $\tilde{e}$ can vary. In Sect. 3.3 this assumption is relaxed.

## 2.4 Individual choice

Individuals have perfect knowledge of what level of $\tilde{e}$ is implemented and also know $G(.)$ and $I(.)$.[6] They know that on the one hand they face a certain probability of being punished if they are innocent and on the other hand they also face a certain probability of being set free if they committed the crime.

[6]In reality people know the probabilities of errors by observing precedents, past court decisions and jurisprudence. In a more sophisticated model their knowledge could be the result of observing trial outcomes and sentences as they are made public. On the role of courts' errors in parties' behavior, see Tullock (1994).

### *2.4.1 The probability of detection q*

Let $q$ be the probability of detection, $0 < q \leq 1$, that is to say the probability that the police arrest an individual (either innocent or guilty) in connection with a crime. In this model, $q$ is exogenous as it simply depends on police efficiency or on circumstance. Once the police charge an individual, they bring him to court where he goes through a process that establishes whether he is to be punished. Note that the probability of detection $q$ and the probabilities of type-I and type-II errors are independent. The probability of being brought in front of the court as a defendant is the same both for the guilty and for the innocent. This assumption implies that defendants are detected by *monitoring*[7] *as opposed to investigation*.[8] In the paper the monitoring technology is assumed to be given because it simplifies calculation without loss of generality.[9] Investigation should qualitatively affect our model (but not necessarily jeopardize our results) only as long as a Bayesian judge may infer a defendant's guilt from the fact that guilty persons are more likely to be detected than innocent ones in the first place. However judges are required to presume the defendant's innocence until proven guilty 'beyond a shadow of a doubt', in order to avoid committing a type-I error.

### *2.4.2 The private benefits and costs from crime*

Define $w$ as the private gain from crime, which is known only to the individual. Let $c_p$ be the private cost of punishment suffered by the individual after a verdict of guilty. This is the disutility suffered from fines, imprisonment or other kinds of punishment.[10]

Individuals, who are assumed to be rational and risk-neutral, choose their action by comparing the expected utility from obeying the law $[-q(1-I(\tilde{e}))c_p]$ and the expected utility of committing the crime $[w-q(1-G(\tilde{e}))c_p]$.

Thus, an individual commits the crime if:

$$w - q(1-G(\tilde{e}))c_p > -q(1-I(\tilde{e}))c_p \tag{2}$$

that is to say if $w > \tilde{w}$ where

$$\tilde{w} = qc_p[I(\tilde{e}) - G(\tilde{e})] \tag{3}$$

## 2.5 Judicial errors and crime deterrence

Individual gains from crime are unknown $(w)$ but their distribution is not. In particular they are distributed according to a probability distribution $z$ and a cumulative distribution $Z$. By normalizing the population to 1, the probability that an individual decides to commit a crime is $Pr(w > \tilde{w}) = 1 - Z(\tilde{w})$. Note that this also corresponds to the crime rate for the entire population.

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[7] Mookherjee and Png (1992) describe monitoring as the enforcement activity where resources must be committed before information concerning the offense can be received. As such, detection by monitoring is common to the whole population of potential criminals. An example is a speed check for motorists, or a random tax audit.

[8] According to Mookherjee and Png (1992), investigation implies that the authority monitors only a subset of the population (the suspects). Therefore the probability of detection conditioned on guilt is greater than the probability of detection conditioned on innocence.

[9] In fact, with investigation, the number of guilty among the pool of defendants brought to court would be larger and the number of innocent would be smaller, hence $I(e) \gg G(e)$.

[10] On the deterrent effect of punishment see Tullock (1974) and Cox (1994).

**Proposition 1** Png Result. *Wrongful convictions and wrongful acquittals have an equal effect on the crime rate.*

This result can easily be verified. The first derivatives of the probability of crime $1 - Z(\tilde{w})$ with respect to the probabilities of the two types of error are the same: $\frac{d[1-Z(\tilde{w})]}{dG(\tilde{e})} = \frac{d[1-Z(\tilde{w})]}{d(1-I(\tilde{e}))} = qc_p z(\tilde{w}) > 0$. This means that the probability of committing a crime rises equally with increases in the probabilities of type-I and type-II errors.

**Proposition 2** *The crime rate is minimized, and deterrence is maximal when $\tilde{e} = \tilde{e}_{\min}$.*

The first derivative of the probability of committing a crime with respect to the standard of evidence is:

$$\frac{d[1 - Z(\tilde{w})]}{d\tilde{e}} = qc_p z(\tilde{w})[g(\tilde{e}) - i(\tilde{e})]$$

Thus, the probability of committing a crime is a U-shaped function of $\tilde{e}$ with its minimum in $e_{\min}$. Proof is provided in the Appendix A.

It follows that the criminal population is minimized and deterrence is maximal when judicial errors are minimized. This happens for $\tilde{e} = \tilde{e}_{\min}$, which implies $g(\tilde{e}_{\min}) = i(\tilde{e}_{\min})$. In fact, when we move away from $\tilde{e}_{\min}$, the sum of the two errors increases. For instance with $\tilde{e} > \tilde{e}_{\min}$ the increase in correct acquittals $I(.)$ is more than offset by a larger increase in wrongful acquittals $G(.)$.

Finally, if we were to consider only cost-free deterrence, the optimal standard of evidence should be thus set at $\tilde{e}_{\min}$. However, in the next paragraphs we will assert that it is optimal to require an $\tilde{e} > \tilde{e}_{\min}$, that is to say a higher standard of evidence, once we also consider that imposing punishment on convicted people has a social cost.

## 2.6 Social costs from crime

From the social perspective, crime and the law enforcement system imply three types of costs. First, each crime implies a harm ($h$) to society. For simplicity, $w$ is assumed to be a transfer from the victim to the criminal that cancels out. However, this forced transfer produces $h$, which is the socially relevant negative externality caused by the crime. This implies that there is no crime able to produce benefits to the criminal larger than its social costs (including the private costs of the victim).[11] Second, as seen above, punishment implies private costs for individuals ($c_p$).[12] Third, punishing people implies costs to society as well ($c_s$). These costs of punishment are the enforcement costs of imposing both monetary and non-monetary penalties. Non-monetary sanctions by definition have a social cost (Polinsky and Shavell 1984; Shavell 1987). However, even in the case of fines, sanctions have a social cost insofar as their imposition implies the creation of a court system and of public authorities that threaten probabilistically to impose and carry out this form (Polinsky and Shavell 1992).

[11] Were this the case, allowing a non-zero level of crime would be efficient. This was the notion of efficient crime in the original Becker (1968) model. Although the Beckerian approach can easily be implemented, our model presents a cleaner result as all efficient crime we obtain is due to the underdeterrent effect of judicial errors and therefore no need to disentangle it from the efficient level of crime *à la* Becker.

[12] Whether the private benefits of crime should be also considered along with its social costs is still a matter of debate among scholars. Here we include them following Polinsky and Shavell (2009). Note however that this does not affect in any way our main conclusions. On the complex relationship between costly measures against crime, the social cost of crime and deterrence; see also Skogh and Stuart (1982).

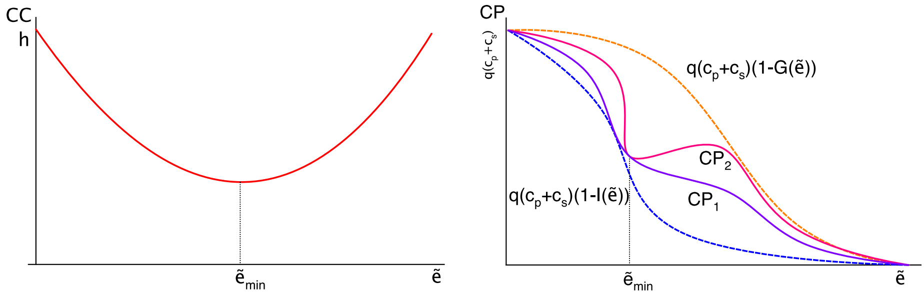


**Fig. 2** The graph on the *left* depicts the costs of crime (CC); the graph on the *right* shows the costs of punishment (CP) which moves between the two retro-cumulative distributions $(1-I)$ and $(1-G)$ scaled by $q(c_p+c_s)$

Assuming risk-neutrality, the problem lies in defining the optimal $\tilde{e}$ that minimizes the expected total costs from crime ($TC$), including the costs of punishment.

$$TC = \underbrace{[1-Z(\tilde{w})]h}_{CC} + \underbrace{[1-Z(\tilde{w})](1-G(\tilde{e}))q[c_s+c_p]}_{CP_G} + \underbrace{Z(\tilde{w})(1-I(\tilde{e}))q[c_s+c_p]}_{CP_I} \quad (4)$$

Term $CC$ of (4) represents the *costs of crime*: the graver and greater the crime rate is, the larger are these costs. Term $CP_G$ represents the expected total (private and social) costs of punishing criminals and term $CP_I$ represents the expected total costs of punishing innocent people. Together, the last two terms are the *total costs of punishment* ($CP$).

**Proposition 3** *The costs of crime* ($CC$) *are minimized when* $\tilde{e}=\tilde{e}_{\min}$.

The costs of crime, captured by the term $CC$, depend on the proportion of individuals opting for crime and on the parameter $h$ which measures the marginal direct cost of crime to society. The function $CC$ behaves as in the left-hand graph of Fig. 2 with its minimum in $\tilde{e}_{\min}$, where errors are at their lowest levels and thus deterrence is maximal. Proposition 3 directly comes from Proposition 2 because $\frac{dCC}{d\tilde{e}} = h\frac{d[1-Z(\tilde{w})]}{d\tilde{e}}$, with $h$ as a positive parameter.

Let us now assess what happens to the *costs of punishment* ($CP$):

**Proposition 4** Min$(CP)$ *is reached for* $\tilde{e}\to\infty$. *CP unequivocally is decreasing over the interval* $[0,\tilde{e}_{\min}]$. *For* $\tilde{e}\in\,]\tilde{e}_{\min},\infty[$, $CP$ *asymptotically converges to zero.*

Let us briefly analyze the $CP$ function. Note that $(q(c_p+c_s))$ is determined by three exogenous parameters and represents the intercept of the $CP$ function; see Fig. 2 on the right. When $\tilde{e}$ is zero, the whole population of arrested persons is convicted and $CP = q(c_p+c_s)$. Thus, our analysis focuses on the two components $1-G(\tilde{e})$ and $1-I(\tilde{e})$, both decreasing in $\tilde{e}$. These two retro-cumulative functions are scaled by $q(c_p+c_s)$ and depicted as the two dashed lines in the right-hand graph of Fig. 2. Note that $1-Z(\hat{w})$ and $Z(\hat{w})$ can be seen as two weights on the terms $CP_G$ and $CP_I$, respectively, since $Z(.)\in[0,1]$. Therefore the $CP$ function moves between $1-G(.)$ and $1-I(.)$. Asymptotically, the $CP$ function converges to zero. Note that without any further specific assumption, beyond $\tilde{e}_{\min}$ $CP$ could either monotonically decrease or even increase before converging to zero (see in Fig. 2 the $CP_1, CP_2$ curves).

However, the shape of the $CP$ function, between $\tilde{e}_{\min}$ and its convergence to $1 - G(.)$, depends on how $Z(\tilde{w})$ changes marginally with respect to $\tilde{e}$. The conditions for the existence of a local maximum of the $CP$ function for $\tilde{e}_{\min} > \tilde{e} > \infty$ are derived in the Appendix A.

### 2.7 The optimal standard of evidence

Finally, by combining the functions $CP$ and $CC$ we can analyze the $TC$ function. Obviously, when punishment is costless the total social costs are determined solely by the costs of crime. In this case, Proposition 1 implies the following straightforward policy implication.

**Result 1** Absent the costs of punishment, the optimal standard of evidence is $\tilde{e}^* = \tilde{e}_{\min}$.

When $(c_p + c_s) = 0$, then the $TC$ function collapses in the $CC$ function. Thus, because of Proposition 3, when there are no costs of punishment, then $\min[TC]$ is reached at $\tilde{e}_{\min}$. In other words, when sanctioning is a perfectly cost-free activity, then the total costs are minimized when deterrence is maximized.

**Proposition 5** *$TC$ monotonically decreases over the interval $[0, \tilde{e}_{\min}]$. In the interval $]\tilde{e}_{\min}, \infty[$ $TC$ can be decreasing, constant, or increasing in $\tilde{e}$. For $\tilde{e} \to \infty$, $TC = h$.*

Defined over the interval $[0, \infty]$, the function $TC$ is always positive and has an intercept equal to $h + q(c_p + c_s)$. Asymptotically, $TC$ converges to $CC$. This occurs because for $\tilde{e} \to \infty$, $CP$ tends to converge to zero and $CC$ thus dominates. $TC$ decreases monotonically over the interval $[0, \tilde{e}_{\min}]$. Note that $TC(\tilde{e}_{\min})$ does not represent a minimum since $\frac{dTC}{d\tilde{e}} = \frac{dCC}{d\tilde{e}} + \frac{dCP}{d\tilde{e}}$, where $\frac{dCC}{d\tilde{e}} \le 0$, $\frac{dCP}{d\tilde{e}} < 0$ for $\tilde{e} \in [0, \tilde{e}_{\min}]$. From this observation we can derive the next result.

**Result 2** When the costs of punishment are positive, the optimal standard of evidence is $\tilde{e}^* > \tilde{e}_{\min}$.

Since $\frac{dTC}{d\tilde{e}}(\tilde{e}_{\min}) < 0$ and $\frac{dTC}{d\tilde{e}}(\tilde{e} \to \infty) > 0$, and because of the assumption of continuity and differentiability, $TC$ has at least one local minimum for $\tilde{e} > \tilde{e}_{\min}$. However, beyond $\tilde{e}_{\min}$ and before unambiguously converging to $CC$, the shape of $TC$ can be complicated by the component $CP$. We draw some conclusions proceeding both with the graphical analysis, and analytically in the Appendix A.

**Corollary 2** *When the costs of punishment are low with respect to the social harm of crime, then $\tilde{e}^*$ tends to be closer to $\tilde{e}_{\min}$. When instead the ratio between costs of punishment and social harm is high, $\tilde{e}^*$ diverges significantly from $\tilde{e}_{\min}$.*

In fact, whether the optimal level of $\tilde{e}^*$ is (significantly) larger than $\tilde{e}_{\min}$ depends on the ratio of the costs of punishment to the harm from crime. When $q(c_p + c_s)/h$ is low, then $\tilde{e}^* \to \tilde{e}_{\min}$. This situation can have two interpretations: (a) crimes are particularly egregious and impose substantial costs on society; or (b) the costs of punishment are relatively low, from both the private and the public perspective. Conversely when $q(c_p + c_s)/h$ is high then $\tilde{e}^* \gg \tilde{e}_{\min}$. This result is depicted in Fig. 3: for relatively low levels of $q(c_p + c_s)/h$ the optimal level of standard of evidence is close to $\tilde{e}_{\min}$. When $q(c_p + c_s)/h$ becomes large (either because the costs of convictions are large or because the harm from crime is small), then the optimal level of standard of evidence rises beyond $\tilde{e}_{\min}$.

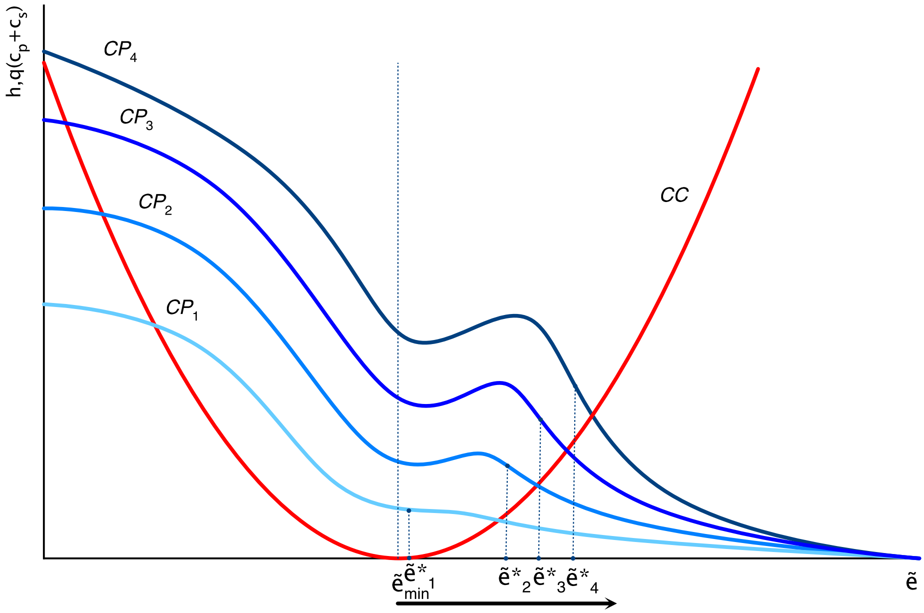


**Fig. 3** The optimal $\tilde{e}$ when $h$ and $q, c_p, c_s$ vary. Note that in the figure, $CC$ has been normalized so as to have $1 - Z(\tilde{e}_{\min}) = 0$. The optimal $\tilde{e}$ minimizes $CC + CP$ and thus the different $\tilde{e}^*$ ($\tilde{e}_1^*, \tilde{e}_2^*, \tilde{e}_3^*, \tilde{e}_4^*$) depicted in the figure are placed where $\frac{dCC}{d\tilde{e}} = -\frac{dCP_{1,2,3,4}}{d\tilde{e}}$

## 3 Some possible extensions

This section discusses and, whenever possible, relaxes the main assumptions of the model.

### 3.1 The different ethical weights of the two errors

As briefly explained in the literature review, other authors put different weights of the two types of errors. This reflects the intuition that punishment of the innocent is inherently harmful to others and breaches social norms. The (un)ethical burden of type-I errors can easily be implemented in the model and simply reinforces the main argument that type-I errors should be exchanged for type-II errors so long as the marginal costs of less effective deterrence do not exceed the marginal benefits of lessening the costs of punishment. By adding ethical weight to type-I errors, or an additional error term for the moral costs of type-I errors, the optimal $\tilde{e}$ becomes even larger. The merit of the present approach is that the optimal standard of evidence is shown to exceed the one that minimizes the number of judicial errors, net of ethical considerations that the authors nevertheless share.

### 3.2 Evidence production

The key variable of the model is the standard of evidence $\tilde{e}$. In the model we assume that the production of evidence itself is a costless activity of the parties to the trial.

Search costs of producing such evidence could also be considered and two additional terms could be added to the function of total costs: one term, increasing in $\tilde{e}$, representing the search costs for the prosecutor; and the other term, representing search costs for the defendant, which is decreasing in $\tilde{e}$. In fact, given parties' conflicting interests, the two functions have opposite slopes because there exists at least a partial substitution effect between the two costs. With further assumptions on who, between the defendant and the prosecutor, is the more efficient evidence producer, optimality can be derived.

### 3.3 Accuracy and forensic technology

In the model we assume that accuracy is costless for the parties at trial. We can however relax this assumption and show what happens when the costs of accuracy are added to the trade-off between the deterrence of crime and the costs of punishment.

Many features of the legal process may influence the level of accuracy of an adjudication. Think for instance of the training of prosecutors and the forensic technology to which they have access to. More accuracy allows the prosecutor to collect better evidence of guilt and thus helps the court to better distinguish guilty individuals from innocent ones. For a given standard of evidence ($\tilde{e}$) required by the procedure, advances in forensic technology almost always improve the ability of parties in a trial to produce incriminating evidence for the guilty and exculpatory evidence for the innocent. This implies that the distributions of $e$ are less dispersed and more distinguishable (see Fig. 1). Note that improved forensic technology on average reduces the probability of both type-I and type-II errors.

In the model there are no direct costs of accuracy. However, greater evidentiary accuracy likely is to be achieved only at some cost and therefore the goal becomes the assessment of the optimal investment that balances the trade-off between the higher costs of more evidentiary precision and the benefits of more effective deterrence of criminal activity (Kaplow 1994; Kaplow and Shavell 1994).

The introduction of a cost term—let us call it $c_a$—in (4) linked with lower levels of both errors does not change the results of the paper qualitatively. Suppose that $G(.)$ and $I(.)$ also depend on investments in accuracy and thus are functions of $c_a$. Then, when $\tilde{e} > \tilde{e}_{\min}$ we still have on the one hand increasing costs of crime (now made by $CC$ in (4) plus the additional costs of more evidentiary precision $c_a$), while on the other hand we have the costs of punishment that now decrease more dramatically because increases in accuracy decrease the probabilities of both types of error. Still, the optimal $\tilde{e}$ is larger than the one that minimizes the sum of the two errors. To compare our result with Kaplow and Shavell (1994), note that accuracy would be maximized for $\tilde{e}_{\min}$ (as accuracy is exactly measured as the sum of the two errors). Instead in our work we show that it is optimal to sacrifice some accuracy in order to reduce the costs of punishment.

### 3.4 Inquisitorial versus adversarial systems

Our model can be adapted to fit both inquisitorial and adversarial procedures. In common law systems, where the adversarial approach is prevalent, the prosecutor and the defendant are delegated to fact-finding (Garoupa 2009). The court acts as an impartial referee and must rule on the case relying only on the evidence presented by parties. The conflicting nature of parties' interests certainly induces strategic behavior.[13] As shown in the literature,[14] the

[13] See Shavell (1989). On the adversarial system and strategic interactions between prosecutor and defendant see Dewatripont and Tirole (1999), Froeb and Kobayashi (2001). For a review of strategic interactions between parties in civil litigation, see Hylton and Lin (2009).

[14] See Thibaut et al. (1972), Shin (1998), Dewatripont and Tirole (1999), Parisi (2002).

adversarial model thus should favor an intense production of evidence, which on the one hand increases accuracy (see 3.3) but on the other hand implies large search costs (see 3.2).

The inquisitorial approach often characterizing civil law systems is stylized in a different manner. Impartial prosecutors are responsible for collecting the evidence at trial and they are supposed to work also in the interest of the defendant. The prosecutor is a bureaucrat in the same way as the judge who adjudicates the case. The involvement of the defense lawyer is usually limited to monitoring tasks. In this outline system, no relevant strategic interaction between the defense lawyer and the prosecutor occurs as the trial takes place after all the evidence has been collected (Palumbo 2001; Garoupa 2009). Under the inquisitorial system we should thus expect less resource dissipation due to the search costs of both parties but at the same time less accuracy (Tullock 1975; Palumbo 2001).

The reality of actual trials makes the two systems more similar than the previous categorization may induce one to think. The model would predict a very active defendant under the adversarial system and conversely quite a passive one under the inquisitorial system. Indeed defendants have often a very passive role in both systems as a large fraction of them are represented by *pro bono* counselors or public defenders (Rhee 1996; Sandefur 2007; Seron et al. 2001) whose effort is basically justified (for those of them who have it) by intrinsic motivation. In this context, the high standard of evidence that we justify because of punishment costs serves the interest of passive defendants under both systems.

Furthermore, in the adversarial system, the prosecutor is predicted to have a very aggressive approach [15] while in the inquisitorial system his ideal search for the truth should lead to a more balanced approach. Again, the reality is quite different. Generally, prosecutors seem to respond to more direct incentives: between conviction rates and flourishing legal careers, success in sentencing a large percentage of defendants in criminal cases burnishes prosecutors' reputations and places them on paths for elevation to higher public office, including judgeships and election or appointment to the executive branch of government as attorneys general (Glaeser et al. 2000; Long and Boylan 2005; Garoupa and Stephen 2008; Garoupa 2009).[16] These career incentives are often parametrized on the record of convictions (Meares 1995), and even where no direct link is established between convictions and career often a high level of convictions builds the reputation of a successful prosecutor (Rubin 1983). Therefore the high standard of evidence that is justified in the paper because of punishment costs becomes an important safeguard against prosecutors' biases which may occur in both inquisitorial and adversarial systems (see also Hylton and Khanna 2007).

## 4 Conclusions and policy implications

Criminal procedure is inherently exposed to the risk of producing type-I (wrongful convictions) and type-II errors (wrongful acquittals). Many pro-defendant safeguards are usually set against the occurrence of type-I errors although this inevitably implies that more type-II errors are produced. On the other hand, the prevalent theory of optimal deterrence prescribes the minimization of errors in order to achieve optimality. With the present paper we endogenize the source of the asymmetry between the two errors and we offer an explanation for

[15] On the varying ideologies and propensities of judges in common law systems, see Fon and Parisi (2003).

[16] See Gordon and Huber (2002) and Dyke (2007); for an extreme example of preference for harsh sanctions and higher incarceration rates, see Belova and Gregory (2009).

why more modern legal processes impose heavier evidentiary burdens on prosecutors representing the state, requiring them to prove a criminal defendant's guilt "beyond a reasonable doubt" without turning to moral, legal or philosophical arguments.

The intuition of the model is quite simple. Suppose that a wrongful conviction can be traded off against wrongful acquittal by slightly increasing the standard of evidence. On balance deterrence remains constant, since it is equally affected by the errors. Simultaneously, the costs of punishment decrease, as more guilty defendants are acquitted and more innocent people avoid wrongful punishment. Therefore it is socially desirable to raise the level of $\tilde{e}$. However, deterrence remains constant only for negligible changes in the standard of evidence. In fact, since the trade-off between errors is not linear, at a certain point one fewer wrongful conviction will be traded off against too many wrongful acquittals, causing a reduction in deterrence that cannot be further compensated for by the saved costs of punishment. The paper thus shows how the optimal level of the standard of evidence required to reach a conviction is the one that balances the *costs of additional crime* (*lost deterrence*) with the *saved costs* of *punishing* both fewer guilty people and fewer innocent ones. We then show that the optimal level of $\tilde{e}$ is close to the one that minimizes errors only when the harm from crime is particularly severe or when the costs of punishment are particularly low. When instead the costs of punishment are significant, the optimal level of $\tilde{e}$ rises and thus so too does the ratio of type-I to type-II errors. These results have very intuitive implications: for a given level of harm of a given unlawful action, when the costs of punishment are low, the public authority may justify a lesser evidentiary standard than when costs of punishment are high. This is the case of administrative sanctions with respect to criminal cases. Furthermore, within criminal cases, when the costs (private and/or social) of putting people in jail are significant, the public authority may prefer to raise pro-defendant safeguards in order to reduce those costs.

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## Appendix A

### A.1 Proof of Lemma 1

Proof by contradiction. Recall that $I(e), G(e)$ are continuous and differentiable over the interval $(0, \infty)$. Furthermore, $G(e) \leq I(e)\ \forall e$, with strict inequality at some $e$, because of the assumption of f.o.s.d. The properties of any cumulative distribution imply that: (a) $\lim_{e\to 0} G(e), I(e) = 0$, (b) $\lim_{e\to\infty} G(e), I(e) = 1$, and (c) both cumulative distributions are strictly monotonic and non-decreasing in $e$. First, let us see what happens in the neighborhood of 0. Because of (a), and since $I(e) > G(e)$ also for $e \to 0$, then for $e$ arbitrarily close to 0, it must be that $i(e) > g(e)$. Now suppose (*ad absurdum*) that $i(e) > g(e)$ $\forall, e \in (0, \infty)$. As of (b) there must exist an $e_2$, even arbitrarily close to $\infty$, for which $G(e_2) = 1$, otherwise $G$ is not a cumulative function. Then there must exist also an $e_1 < e_2$ for which $I(e_1) = 1$. But then, $i(e) \leq g(e)$ at least for $e \in [e_1, e_2]$.

### A.2 Proof of Proposition 2

Let us examine whether $\frac{d[1-Z(\tilde{w})]}{d\tilde{e}} = qc_p z(\tilde{w})[g(\tilde{e}) - i(\tilde{e})] \lesseqgtr 0$. Note that, for $g(\tilde{e}) < i(\tilde{e})$, $\frac{d[1-Z(\tilde{w})]}{d\tilde{e}} < 0$, while for $g(\tilde{e}) > i(\tilde{e})$, $\frac{d[1-Z(\tilde{w})]}{d\tilde{e}} > 0$. Finally, $\frac{d[1-Z(\tilde{w})]}{d\tilde{e}} = 0$ for $i(\tilde{e}) = g(\tilde{e})$.

From Lemma 1, recall that on the left of $\tilde{e}_{\min}$, $g(\tilde{e}) < i(\tilde{e})$, while on the right of $\tilde{e}_{\min}$, $g(\tilde{e}) > i(\tilde{e})$. Thus, we can conclude that the probability of committing a crime as a function of $\tilde{e}$ is U-shaped and the smallest possible probability of committing a crime is at the level of $e_{\min}$, where $g(\tilde{e}_{\min}) = i(\tilde{e}_{\min})$ and the distance between the two cumulative distributions as large as possible.

### A.3 Proof of Proposition 4

Let us study the $CP$ function:

$$CP = q[c_s + c_p]\{[1 - Z(\tilde{w})](1 - G(\tilde{e})) + Z(\tilde{w})(1 - I(\tilde{e}))\}$$

The $CP$ function is non-negative for every $\tilde{e}$. Moreover for $\tilde{e} = 0$, $CP = q[c_s + c_p]$ and for $\tilde{e} \to \infty$, $CP = 0$.

We then derive $CP$ with respect to $\tilde{e}$.

$$\frac{dCP}{d\tilde{e}} = q[c_s + c_p]\frac{d[[1 - Z(\tilde{w})](1 - G(\tilde{e})) + Z(\tilde{w})(1 - I(\tilde{e}))]}{d\tilde{e}}$$

$$\frac{dCP}{d\tilde{e}} = \underbrace{q[c_s + c_p]qc_p z(\tilde{w})[g(\tilde{e}) - i(\tilde{e})][I(\tilde{e}) - G(\tilde{e})]}_{\lesseqgtr 0}$$
$$- \underbrace{q[c_s + c_p][g(\tilde{e})[1 - Z(\tilde{w})] + i(\tilde{e})Z(\tilde{w})]}_{<0, \forall\tilde{e}}$$

Note that the second term of the equation above is always negative. We first focus on how $\frac{dCP}{d\tilde{e}}$ behaves over the interval $[0, \tilde{e}_{\min}]$ and we concentrate on the first term. Over this interval, $g(\tilde{e}) \leq i(\tilde{e})$ (see Lemma 1) and therefore also the first term is negative or null. Thus on that interval $\frac{dCP}{d\tilde{e}} < 0$. Note that the first derivative also is negative for $\tilde{e} = \tilde{e}_{\min}$. Thus, $CP(\tilde{e}_{\min})$ represents neither the global nor a local minimum of the continuous $CP$ function and therefore the $CP$ function unambiguously is decreasing over the interval $[0, \tilde{e}_{\min}]$.

We now look beyond $\tilde{e}_{\min}$, and before $CP$'s convergence to zero following the upper bound function $1 - G(e)$.

Rearranging $\frac{d(.)}{d\tilde{e}}$ we obtain that $\frac{d(.)}{d\tilde{e}}$ is non-negative when:

$$1 - \frac{i(\tilde{e})}{g(\tilde{e})} \geq \frac{1}{z(\tilde{w})qc_p[I(\tilde{e}) - G(\tilde{e})] + Z(\tilde{w})} \tag{5}$$

- The right-hand term of the condition above is always positive. Note, once again, that the condition could hold only for $\frac{i}{g} < 1$, thus for $\tilde{e} > \tilde{e}_{\min}$. The right-hand term of the inequality negatively depends on the distance between the two functions $(1 - G(e))$ and $(1 - I(e))$ that bound the $CP$ function. This distance decreases by increasing $\tilde{e}$. Furthermore, the second term negatively depends on $Z(\tilde{w})$ which is decreasing in $\tilde{e} > \tilde{e}_{\min}$. This means that the condition necessary for the $CP$ function to be positive is hard to satisfy for large values of $\tilde{e}$. If the $CP$ function becomes increasing in $\tilde{e}$, this can happen only over a relatively small interval beyond $\tilde{e}_{\min}$.
- Note that (5) also depends on how the density function of wealth $z$ behaves. Particularly, the density function also describes the first derivative of the cumulative function of the gain from crime—calculated in $\tilde{w}$—and describes how fast the function is changing. Beyond $\tilde{e}_{\min r}$, if the weight $(1 - Z(\tilde{w}))$ increases smoothly, the condition is more hard to satisfy.

In conclusion, because we cannot exclude the possibility that the $CP$ function is non-decreasing over a certain interval beyond $\tilde{e}_{\min}$ and before its convergence to zero, a local maximum for $\tilde{e}_{\min} < \tilde{e} \ll \infty$ could exist in that event.

### A.4 Proof of Proposition 5

We study the function of total costs $TC$.

$$\begin{aligned} TC = {} & [1 - Z(\tilde{w})]h + [1 - Z(\tilde{w})]q(1 - G(\tilde{e}))[c_s + c_p] \\ & + Z(\tilde{w})q(1 - I(\tilde{e}))[c_s + c_p] \end{aligned} \tag{6}$$

We derive $TC$ with respect to $\tilde{e}$.

$$\begin{aligned} \frac{dTC}{d\tilde{e}} &= \frac{dCC}{d\tilde{e}} + \frac{dCP}{d\tilde{e}} \\ &= \underbrace{qc_p z(\tilde{w})[g(\tilde{e}) - i(\tilde{e})][h + q[c_s + c_p](I(\tilde{e}) - G(\tilde{e}))]}_{1} \\ &\quad - \underbrace{q[c_s + c_p][[1 - Z(\tilde{w})]g(\tilde{e}) + Z(\tilde{w})i(\tilde{e})]}_{2} \end{aligned}$$

Note that the second term of $\frac{dTC}{d\tilde{e}}$ is always negative. Over the interval $[0, \tilde{e}_{\min}]$, $g(\tilde{e}) \leq i(\tilde{e})$ and thus, for $\tilde{e} \in [0, \tilde{e}_{\min}]$, the first term also is negative. This implies that $\frac{dTC}{d\tilde{e}} < 0$ over the interval. Let us underline how the function behaves in $\tilde{e}_{\min}$. Recalling that $g(\tilde{e}_{\min}) = i(\tilde{e}_{\min})$, note that

$$\frac{dTC(\tilde{e}_{\min})}{d\tilde{e}} = -g(\tilde{e}_{\min})q(c_s + c_p) < 0$$

If the costs of punishment (private and/or social) are positive, then $TC$ is not minimized in $e_{\min}$.

We study $TC$ for $\tilde{e} > \tilde{e}_{\min}$. We know that $g(\tilde{e}) > i(\tilde{e})$ because of Lemma 1 and thus, in the interval $\frac{dTC}{d\tilde{e}} \lesseqgtr 0$.

Particularly, $\frac{dTC}{d\tilde{e}} > 0$ if:

$$1 - \frac{i(\tilde{e})}{g(\tilde{e})} > \frac{1}{z(\tilde{w})qc_p(I(\tilde{e}) - G(\tilde{e})) + Z(\tilde{w}) + z(\tilde{w})\frac{c_p}{c_p + c_s}h}$$

Note that:

- The right-hand term of the condition above is always positive. Once again, the condition can hold only for $\frac{i}{g} < 1$, thus for $\tilde{e} > \tilde{e}_{\min}$.
- However, the right-hand term of the inequality is smaller than the right-hand term of (5); thus the condition for $TC$ to increase is more easily satisfied than the condition for $CP$ to increase. The $TC$ function can be increasing in $\tilde{e}$ beyond $\tilde{e}_{\min}$ even if the $CP$ function is always decreasing.
- Particularly, the right-hand term negatively depends on $h$ and positively depends on the social costs of conviction. The $TC$ function is always decreasing over the interval $[0, \tilde{e}_{\min}]$; beyond that interval its shape depends on the relative weight of the social harm from crime and the costs of punishment.

- Once again it is evident that $\tilde{e}_{\min}$ does not minimize $TC$ because $\frac{g(\tilde{e}_{\min})}{i(\tilde{e}_{\min})} = 1$ and the first order condition cannot be satisfied.

In conclusion, it is trivial to observe that if the $TC$ function is always decreasing in $\tilde{e}$, the optimal level of $\tilde{e}$ that minimizes the total social costs of crime is larger than $\tilde{e}_{\min}$ ($\tilde{e}^* \to \infty$). However, even if $TC$ becomes increasing in $\tilde{e}$, this occurs for $\tilde{e} > \tilde{e}_{\min}$. *Ceteris paribus*, for a low $h$ and a large cost of punishment the optimal level of $\tilde{e}$ shifts to the right.

## References


Allen, R., & Laudan, L. (2008). Deadly dilemmas. *Texas Tech Law Review*, *41*, 33.

Allen, R. J., & Pardo, M. S. (2007). The problematic value of mathematical models of evidence. *Journal of Legal Studies*, *36*(1), 107–140.

Becker, G. (1968). Crime and punishment: an economic approach. *Journal of Political Economy*, *76*, 169–217.

Belova, E., & Gregory, P. (2009). Political economy of crime and punishment under Stalin. *Public Choice*, *140*(3), 463–478.

Blackstone, W. (1769). *Commentaries on the laws of England* (Vol. 4). Oxford: Clarendon Press.

Cox, G. (1994). A note on crime and punishment. *Public Choice*, *78*(1), 115–124.

Craswell, R., & Calfee, J. (1986). Deterrence and uncertain legal standards. *Journal of Law, Economics, and Organization*, *2*(2), 279–303.

Davis, M. L. (1994). The value of truth and the optimal standard of proof in legal disputes. *Journal of Law, Economics, and Organization*, *10*(2), 343–359.

Demougin, D., & Fluet, C. (2006). Preponderance of evidence. *European Economic Review*, *50*(4), 963–976.

Dewatripont, M., & Tirole, J. (1999). Advocates. *Journal of Political Economy*, *107*(1), 1–39.

Dyke, A. (2007). Electoral cycles in the administration of criminal justice. *Public Choice*, *133*(3), 417–437.

Feess, E., & Wohlschlegel, A. (2009). Why higher punishment may reduce deterrence. *Economics Letters*, *104*(2), 69–71.

Fon, V., & Parisi, F. (2003). Litigation and the evolution of legal remedies: a dynamic model. *Public Choice*, *116*(3–4), 419–433.

Froeb, L., & Kobayashi, B. (2001). Evidence production in adversarial vs. inquisitorial regimes. *Economics Letters*, *70*(2), 267–272.

Garoupa, N. (2009). Some reflections on the economics of prosecutors: mandatory vs. selective prosecution. *International Review of Law and Economics*, *29*(1), 25–28.

Garoupa, N., & Rizzolli, M. (2012, forthcoming). Wrongful convictions do lower deterrence. *Journal of Institutional and Theoretical Economics, 168*.

Garoupa, N., & Stephen, F. (2008). Why plea-bargaining fails to achieve results in so many criminal justice systems: a new framework for assessment. *Maastricht Journal of European and Comparative Law*, *15*(3), 319–354.

Glaeser, E. L., Kessler, D. P., & Morrison Piehl, A. (2000). What do prosecutors maximize? An analysis of the federalization of drug crimes. *American Law and Economics Review*, *2*(2), 259–290.

Gordon, S. C., & Huber, G. A. (2002). Information, evaluation, and the electoral incentives of criminal prosecutors. *American Journal of Political Science*, *46*(2), 334–351.

Hylton, K., & Lin, H. (2009). *Trial selection theory and evidence: a review* (Working Paper No. 09-27). Boston University School of Law.

Hylton, K. N., & Khanna, V. S. (2007). A public choice theory of criminal procedure. *Supreme Court Economic Review*, *15*, 61–118.

Kaplow, L. (1994). The value of accuracy in adjudication: an economic analysis. *Journal of Legal Studies*, *23*(1), 307–401.

Kaplow, L., & Shavell, S. (1994). Accuracy in the determination of liability. *Journal of Law and Economics*, *37*(1), 1–15.

Lando, H. (2006). Does wrongful conviction lower deterrence? *Journal of Legal Studies*, *35*(2), 327–338.

Lando, H. (2009). Prevention of crime and the optimal standard of proof in criminal law. *Review of Law and Economics*, *5*(1), 33–52.

Long, C. X., & Boylan, R. T. (2005). Salaries, plea rates, and the career objectives of federal prosecutors. *Journal of Law and Economics*, *48*, 627–709.

Meares, T. L. (1995). Rewards for good behavior: influencing prosecutorial discretion and conduct with financial incentives. *Fordham Law Review*, *64*, 851–919.

Miceli, T. (1990). Optimal prosecution of defendants whose guilt is uncertain. *Journal of Law, Economics, and Organization*, *6*(1), 189.
Miceli, T. J. (2009). Criminal procedure. In *Criminal law and economics—encyclopedia of law & economics* (Vol. 3). Cheltenham: Edward Elgar.
Mookherjee, D., & Png, I. P. L. (1992). Monitoring vis-a-vis investigation in enforcement of law. *American Economic Review*, *82*(3), 556–565.
Mungan, M. (2011). A utilitarian justification for heightened standards of proof in criminal trials. *Journal of Institutional and Theoretical Economics*, *167*(2), 352–370.
Ognedal, T. (2005). Should the standard of proof be lowered to reduce crime? *International Review of Law and Economics*, *25*(1), 45–61.
Palumbo, G. (2001). Trial procedures and optimal limits on proof-taking. *International Review of Law and Economics*, *21*, 309–327.
Parisi, F. (2002). Rent-seeking through litigation: adversarial and inquisitorial systems compared. *International Review of Law and Economics*, *22*(2), 193–216.
Png, I. P. L. (1986). Optimal subsidies and damages in the presence of judicial error. *International Review of Law and Economics*, *6*(1), 101–105.
Polinsky, A. M., & Shavell, S. (1984). The optimal use of fines and imprisonment. *Journal of Public Economics*, *24*(1), 89–99.
Polinsky, A., & Shavell, S. (1992). Enforcement costs and the optimal magnitude and probability of fines. *Journal of Law and Economics*, *35*(1), 133–148.
Polinsky, A. M., & Shavell, S. (2009). Public enforcement of law. In *Criminal law and economics—encyclopedia of law and economics* (Vol. 3, pp. 1–60). Amsterdam: Edward Elgar.
Posner, R. A. (2007). *Economic analysis of law*. New York: Aspen Publishers.
Rhee, C. S. (1996). Pro bono, pro se. *Yale Law Journal*, *105*(6), 1719–1724.
Rubin, P.H. (1983). The objectives of private and public judges. *Public Choice*, *41*, 133–137.
Rubinfeld, D. L., & Sappington, D. E. M. (1987). Efficient awards and standards of proof in judicial proceedings. *RAND Journal of Economics*, *18*(2), 308–315.
Sanchirico, C. W. (1997). The burden of proof in civil litigation: a simple model of mechanism design. *International Review of Law and Economics*, *17*(3), 431–447.
Sandefur, R. L. (2007). Lawyers' pro bono service and American-style civil legal assistance. *Law and Society Review*, *41*(1), 79–112.
Schrag, J., & Scotchmer, S. (1994). Crime and prejudice: the use of character evidence in criminal trials. *Journal of Law, Economics, and Organization*, *10*(2), 319–342.
Seron, C., van Ryzin, G., Frankel, M., & Kovath, J. (2001). The impact of legal counsel on outcomes for poor tenants in New York City's housing court: results of a randomized experiment. *Law and Society Review*, *35*(2), 419–434.
Shavell, S. (1987). The optimal use of nonmonetary sanctions as a deterrent. *American Economic Review*, *77*(4), 584–592.
Shavell, S. (1989). Sharing of information prior to settlement or litigation. *RAND Journal of Economics*, *20*(2), 183–195.
Shin, H. S. (1998). Adversarial and inquisitorial procedures in arbitration. *RAND Journal of Economics*, *29*(2), 378–405.
Skogh, G., & Stuart, C. (1982). An economic analysis of crime rates, punishment, and the social consequences of crime. *Public Choice*, *38*(2), 171–179.
Thibaut, J., Walker, L., & Lind, E. (1972). Adversary presentation and bias in legal decisionmaking. *Harvard Law Review*, *86*(2), 386–401.
Tullock, G. (1974). Does punishment deter crime? *Public Interest*, *36*, 103–111.
Tullock, G. (1975). On the efficient organization of trials. *Kyklos*, *28*(4), 745–762.
Tullock, G. (1980). *Trials on trial*. New York: Columbia University Press.
Tullock, G. (1994). Court errors. *European Journal of Law and Economics*, *1*(1), 9–21.
Yilankaya, O. (2002). A model of evidence production and optimal standard of proof and penalty in criminal trials. *Canadian Journal of Economics*, *35*(2), 385–409.