Contingent Plea Agreement for Witness Testimony*

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March 20, 2025

Abstract. Prosecutor can offer leniency to an eyewitness in exchange for testimony. There is a concern that allowing the prosecutor to make the leniency contingent upon a successful conviction in the trial will produce more perjury and the court has thrown out some testimonies obtained through such contingent plea agreements. This paper uses a Bayesian jury model to examine the impact of allowing a conviction-motivated prosecutor to design a contingent contract. It finds that when the additional evidence in the trial is not very precise, a prosecutor may prefer a contingent contract that is socially undesirable: it increases the chance of innocent conviction and reduces the chance of guilty conviction compared to the non-contingent contract the prosecutor would have chosen. However, when the additional evidence is more informative and the prosecutor faces a binding constraint on the leniency he can offer, he may choose a contingent contract that is socially desirable: it reduces the chance of innocent conviction and increases the chance of guilty conviction. We show that for a range of informativeness of the additional evidence, a properly designed limit on the amount of leniency can always allow the contingency to reduce innocent conviction and increase guilty conviction.

Keywords: contingent plea agreement, perjury, eyewitness, plea bargain, evidence, information acquisition, leniency, immunity

*We thank helpful comments from Nate Atkinson, Scott Baker, Xinyu Hua, and the audience of the Latin American Workshop in Law and Economics and the Thirteenth Annual Law and Economic Theory Conference at University of Michigan. francesxu312@gmail.com. AWickelgren@law.utexas.edu.

JEL Classification. K13; K14; K41; D83

1. Introduction

Courts have long accepted the prosecutor's practice of offering leniency to a witness for testifying against another defendant. The Fifth Circuit has commented that "no practice is more ingrained in our criminal justice system than the practice of the government calling a witness who is an accessory to the crime for which the defendant is charged and having that witness testify under a plea bargain that promises him a reduced sentence."[1] Courts permit these plea agreements for the purpose of obtaining information and recognize them as a proper exercise of prosecutorial authority.[2]

However, many courts have been suspicious of testimonies obtained through plea bargain agreement where the leniency is contingent upon the outcome of the testimony. Defendants argue that the contingent nature of the plea bargain agreement causes the witness to go to any length, including perjury, to obtain the benefits of their bargain.[3] A notable case is *United States v. Waterman*.[4] In *Waterman*, the prosecutor promised the witness a two-year reduction in sentence if the grand jury handed down more indictments against the defendant Waterman. An Eighth Circuit panel held that the witness's testimony violated Waterman's due process rights because the government offered favorable treatment to the witness contingent upon the outcome of his testimony. However, the evenly divided Eighth Circuit vacated the panel decision and affirmed the district court's determination that the contingent agreement did not violate due process. On this same issue, courts have many varied outcomes, with some court decisions holding that testimony obtained through contingent plea bargains violates the defendant's due process rights, and other decisions holding that the prosecution could encourage full cooperation more effectively by using contingent agreements[5], and that the contingent agreement did not put impermissible pressure upon the witness to lie, and contingency should only affect the weight of the evidence, not its admissibility.[6] Legal scholars have argued for holding contingent agreement unconstitutional and disallowing them altogether, e.g. Beeman (1986) and Leimbach (2009). While the A.B.A. Standards for the Prosecution Function does explicitly

[1] United States v. Cervantes-Pacheco, 826 F.2d 310, 315 (5th Cir. 1987).

[2] See, e.g., United States v. Librach, 536 F.2d 1228 (8th Cir.), cert. denied, 429 U.S. 939 (1976); see also A.B.A., STANDARDS RELATING TO THE ADMINISTRATION OF CRIMINAL JUSTICE, THE PROSECUTION FUNCTION Standard 3-4.4 (xi).

[3] Beeman (1986) provided detailed accounts of the varied court decisions on the issue.

[4] 732 F.2d 1527 (1984), vacated en banc, No. 83-2159 (8th Cir. Sept. 20, 1984), cert. denied, 471 U.S. 1065 (1985).

[5] E.g., United States v. Dailey, 589 F. Supp. 561 (D. Mass. 1984).

[6] E.g., United States v. Kimble, 719 F.2d 1253 (5th Cir. 1983), cert. denied, 464 U.S. 1073 (1984).

prohibit the payment to an expert witness to be contingent upon the testimony or the result in the case[7], the A.B.A has not prohibited contingent plea bargain agreements with non-expert witness. Therefore, it is important to understand the impact of allowing contingent plea agreement for witness testimony.

We analyze this impact with a model of a prosecutor whose objective is to maximize the probability of conviction and a Bayesian jury that convicts if and only if the posterior probability of guilt exceeds a fixed threshold. There is a witness who if privately informed of the defendant's guilt, who is offered leniency in exchange for testifying against the defendant. We consider both non-contingent and contingent leniency agreements. This witness also has a privately known cost of testifying and an additional (publicly known) cost of lying. Thus, any offer of leniency (contingent or not), as long as it isn't too large, is more likely to be accepted by a truthful witness (the defendant is guilty) than a lying witness (the defendant is innocent). In addition to the possible witness testimony, there will be additional informative evidence presented at trial. We capture this additional evidence with a binary informative signal, either in favor or against the prosecutor's case.

When the prosecutor is restricted to only offer non-contingent contract, the prosecutor faces the trade-off over whether to pursue what we call a safe strategy or a risky strategy. In the safe strategy, the prosecutor's offers very little leniency, so that the existence of testimony is so informative of guilt that the jury convicts the defendant even if the additional signal is unfavorable to the prosecutor. (Note, that if the leniency offer is less than or equal to the cost of lying, all witnesses will tell the truth.) Under the risky strategy, the prosecutor offers greater leniency that induces testimony by more witnesses and a much higher fraction of lying witnesses. In this case, the testimony will only result in a conviction when the additional signal is favorable. The safe strategy guarantees conviction whenever there is testimony, but it induces much less testimony than the risky strategy.

When contingency is allowed, contingency only changes the witness' incentives if the trial outcome will be risky: conviction only happens if the additional evidence is favorable. Contingency adds to the credibility of the testimony because an honest witness's testimony is more likely to be corroborated with a favorable signal and therefore an honest witness is more likely to receive the conviction-contingent leniency than a dishonest one. This added credibility allows the prosecutor to increase the leniency offer while still making it possible for the jury's posterior probability after receiving the favorable signal to exceed

[7]Standard 3-3.5 (f).

the standard of proof. Without any limit on the amount of leniency, a contingent contract is always better for the prosecutor than a non-contingent risky one because of this relaxed credibility constraint. Interestingly, although contingency makes false testimony less attractive for any given leniency offer, the prosecutor increases the leniency offer such that there are even more innocent convictions (as well as more guilty convictions than the risky, non-contingent strategy). In fact, innocent convictions can increase so much under a contingent contract that the prosecutor is tempted to pursue a contingent strategy rather than a safe, non-contingent one even when the contingent strategy reduces guilty conviction. The higher amount of innocent conviction outweighs the lower amount of guilty conviction for the prosecutor's payoff, resulting in both types of court errors going up when contingency is allowed. This is clearly a case against allowing contingency.

However, contingency's screening ability can reduce both types of court errors if there is a limit on the amount of leniency the prosecutor can offer. The prosecutor is typically bounded by the amount of the liability of the witness: the witness can at most receive full immunity. There can also be an exogenous regulation that limits the amount of the leniency that can be offered. For example, the judge presiding over the legal case against the witness can refuse to sign off on a plea agreement that gives the witness too much leniency. This paper shows that for cases with sufficiently informative additional evidence, we can always find a limit on the leniency amount such that allowing the prosecutor to write contingent plea agreement strictly reduces innocent conviction and increases guilty conviction. This is a case in favor of allowing the contingency contract and rebukes the commonly held belief that contingency can only lead to more innocent conviction.

The literature

The paper builds on Lee (2024)'s understanding of a biased prosecutor's incentives in designing the plea bargain agreement for witness testimony. Lee (2024) only considered non-contingent contract where the witness is paid as long as the witness testifies and did not allow information other than the witness's testimony in the trial.

In it's model of a Bayesian jury, it is related to Friedman and Wickelgren (2006), Lee and Suen (2020), and Pei and Strulovici (2020). By considering a contingent leniency contract that has a screening effect based on the hidden private information of the witness, this paper is related to the huge literature on screening, which Riley (2001) surveyed.

Friedman and Kontorovich (2011) specifically look at how to set the payment for fact witness when potential corroboration from multiple witnesses provides the court with in-

formation on the credibility of the witnesses and the court can choose a payment scheme that is contingent on the posterior belief that a witness told the truth. This paper explicitly considers the biased incentive of the prosecutor and does not consider inferences based on multiple witnesses. Levmore and Porat (2012) offers several explanations for the observed asymmetry between prosecutor and defense's ability to pay for testimonies, including that the prosecutor is likely to be less biased than the defense and the witnesses against the defendant have a higher cost of testifying than those for the defendant.

There is a literature on plea bargain (Reinganum 1988, Baker and Mezzetti 2001, Daughety and Reinganum 2020), but this literature only considered bargaining that can avoid the current trial, rather than bargaining that can obtain cooperation for a different trial against a different defendant.

There is a theoretical literature examines the issue of perjury through providing proper incentives. Papers in this area include Miller (2001), Sanchirico (2001), Cooters and Emons (2004) and Emons (2005). All these existing models of perjury treats the perjuring witness as an inherently biased information sender and there is no interaction between prosecutors and witnesses.

There is a literature on the leniency program that does not consider the possibility of eliciting false information, but rather focuses on the ex ante incentive to commit crime. Motta and Polo (2003) explores the trade-off between the benefit of obtaining information about the crime through leniency program and the cost of a reduced punishment for the information provider.

The paper is organized as follows. Section 2 sets up the model. Section 3 analyzes the benchmark with contingency banned. Section 4 analyzes the outcome when contingency is allowed. Section 5 analyzes the impact on type 1 and type 2 errors from allowing contingency. Section 6 discuss the possibility of implicit contingency. Section 7 concludes.

2. Model Setup

There are two possible states regarding a defendant $\omega \in \{g, i\}$. They respectively mean that the defendant is guilty or is innocent. The prior belief on state g is $\lambda \geq 0.5$. That is, the prior is that the defendant is more likely to be guilty than not guilty. Otherwise, there is no ground for a charge. A witness is informed of that state. The witness has some legal liability, which the prosecutor can offer to reduce or waive by offering the witness an amount of leniency $x \in [0, \bar{x}]$ in exchange for the witness's testimony against

the defendant, saying the defendant is guilty. Assume there is a cost of testifying, that is distributed uniformly over $[0,1]$; this is the witness's private information. Not testifying costs nothing to the witness regardless of the state. The amount of payment is capped by the liability of the witness, what the judge will approve, or some other externally imposed upper bound. Lying adds an additional cost $k \in (0,1)$ to the witness (more effort to fabricate things, cognitive and psychological cost of lying, expected cost of being detected and penalized for perjury etc.) For simplicity, we assume this common knowledge. We assume that the highest payment possible is not strictly larger than the testifying cost of the most reluctant to testify honest witness: $k < \bar{x} \leq 1$.

After the testimony, the nature generates an exogenous informative signal for the jury. The signal outcome is either G (in favor of the prosecutor) or B (not in favor of the prosecutor). Let $Pr(G|g) = Pr(B|i) = p > 0.5$, so higher p means a more informative exogenous signal.

The timing is the following:

1. Nature determines the state.
2. Prosecutor offers $x \geq 0$ to the witness for testifying. This has to be non-contingent if contingency is not allowed, but can be either contingent or not contingent if contingency is allowed.
3. The witness accepts or rejects.
4. If the witness testifies, the jury observes the payment as well as whether the contract is contingent.
5. The jury receives a binary signal with outcome G or B.
6. The jury chooses to convict or acquit with a standard of proof β_0.

The jury uses Bayes Rule to form their posterior beliefs, convicts if the posterior belief of the defendant being guilty is strictly above β_0, and acquits if it is strictly below β_0. Let NTG denote the outcome of testimony under a non-contingent contract and signal G. Other outcomes are similarly denoted.

Assume that the witness' crime is so minor compared to the crime at issue for the defendant that the prosecutor does not care about the cost of the payment per se. The prosecutor's payoff is the benefit of convicting the defendant, which is normalized to 1, regardless of the state, so the prosecutor maximizes the expected probability of conviction. The witness's payoff is the payment received minus any cost of testifying. All are risk neutral.

Assumption 1. *The signal is not too precise:*

$$p < \bar{\bar{p}} \equiv \frac{1}{1+\theta}, \text{ with } \theta = \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}$$

This assumption says that the signal is not so precise such that the signal G alone can convict (prior to any testimony).

Assumption 2. *The lying cost is not too large relative to the maximum feasible payment:*

$$\frac{k}{\bar{x}} < 1-\theta, \text{ with } \theta = \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}$$

This assumption says that the lying cost is not large enough for it to be a strong enough screening device to let a testimony under a non-contingent contract with the upper bound of payment to be credible enough to convict by itself. The condition in the assumption is equivalent to:

$$\frac{\lambda\bar{x}}{\lambda\bar{x}+(1-\lambda)(\bar{x}-k)} < \beta_0$$

Let E_1 denote the chance of type 1 error and E_2 denote the chance of type 2 error.

3. Only non-contingent contract is allowed

For $x \leq k$, only honest witnesses benefit from testifying, so the testimony is fully credible and will result in a conviction for sure. The chance of testifying is λx. The prosecutor's payoff is then λx.

For $x \in (k, \bar{x}]$, the posterior of the jury depends on the signal as well:

$$\beta_{NTB}(x) = \frac{\lambda x(1-p)}{\lambda x(1-p)+(1-\lambda)(x-k)p} < \frac{\lambda xp}{\lambda xp+(1-\lambda)(x-k)(1-p)} = \beta_{NTG}(x)$$

Lee (2024) implies that a higher x reduces the posteriors $\beta_{NTB}(x)$ and $\beta_{NTG}(x)$. Define $\hat{x}_S$ by $\beta_{NTB}(\hat{x}_S) = \beta_0$ and $\hat{x}_R$ by $\beta_{NTG}(\hat{x}_R) = \beta_0$. Here the subscript S indicates the prosecutor can "safely" guarantee conviction under any signal if x is below the cutoff $\hat{x}_S$ and the subscript R indicates that the prosecutor can only "riskily" achieve conviction under signal

G for non-contingent payment $x \in (\hat{x}_S, \hat{x}_R)$. Algebra gives:

$$\hat{x}_S = \frac{k}{1 - \theta \frac{1-p}{p}} > k$$

$$\hat{x}_R = \frac{k}{1 - \theta \frac{p}{1-p}} > \hat{x}_S$$

The last inequality is due to $p > 0.5$. Assumption 2 implies that $\hat{x}_S < \bar{x}$. If the contract is non-contingent, the prosecutor's payoff is:

$$\Pi_N = \begin{cases} \lambda x & \text{for } x \leq k \\ \Pi_S(x) \equiv \lambda x + (1-\lambda)(x-k) & \text{for } x \in (k, \hat{x}_S] \\ \Pi_R(x) \equiv \lambda p x + (1-\lambda)(x-k)(1-p) & \text{for } x \in (\hat{x}_S, \min\{\hat{x}_R, \bar{x}\}] \\ 0 & \text{for } x \in (\hat{x}_R, \bar{x}] \end{cases}$$

The payoff of the prosecutor increases in x, but has two discrete drops at $x = \hat{x}_S$ and $x = \hat{x}_R$ when $\bar{x} > \hat{x}_R$. The maximized payoff is therefore at $\max\{\Pi_S(\hat{x}_S), \Pi_R(\min\{\hat{x}_R, \bar{x}\})\}$. Note that $\hat{x}_S$ is decreasing in p because more precise signal means it is harder to make signal B credible, so $\Pi_S(\hat{x}_S)$ is decreasing in p. At the same time, $\hat{x}_R$ is increasing in p because more precise signal means it is easier to make signal G credible. Then, $\Pi_R(\hat{x}_R)$ is strictly increasing in p when $x \leq \bar{x}$ is not binding. To see that,

$$\Pi_R(\hat{x}_R) = \lambda p(\hat{x}_R(p)) + (1-\lambda)\theta \frac{p}{1 - \theta \frac{p}{1-p}}$$

The first term is strictly increasing in p. The second term is also strictly increasing in p because $\frac{p}{1-\theta \frac{p}{1-p}}$ is strictly increasing in p. When $p > \bar{p}$, $\hat{x}_R > \bar{x}$, where $\bar{p}$ is defined by

$$\hat{x}_R = \frac{k}{1 - \theta \frac{\bar{p}}{1-\bar{p}}} = \bar{x}$$

Note that $\hat{x}_R(p)$ is increasing in p with $\hat{x}_R(0.5) < \bar{x}$ by Assumption 2 and with $\lim_{p \to 1} \hat{x}_R(p) = \infty$. Therefore, $\bar{p}$ is unique and well defined.

When $p = 0.5$, $\hat{x}_S = \hat{x}_R$, so $\Pi_S(\hat{x}_S) > \Pi_R(\hat{x}_R) = \Pi_R(\min\{\hat{x}_R, \bar{x}\})$. When $p \geq \bar{p}$, $\hat{x}_R \geq \bar{x}$,

so

$$\Pi_R(\min\{\hat{x}_R, \bar{x}\}) - \Pi_S(\hat{x}_S) = \Pi_R(\bar{x}) - \Pi_S(\hat{x}_S) = \frac{[\bar{x}(\beta_0 - \lambda) - k\beta_0(1-\lambda)](1-\lambda)\lambda}{(\beta_0 - \lambda)(\lambda(1-\beta_0) + \beta_0(1-\lambda))}$$
$$= \frac{\bar{x}(1 - \theta - \frac{k}{\bar{x}})\theta}{(1 - \beta_0(1-\theta))(1-\theta^2)} > 0$$

Assumption 2 implies that the numerator is positive. Therefore, when $p \geq \bar{p}$, $\Pi_S(\hat{x}_S) < \Pi_R(\bar{x})$. Then, we have the following lemma about the optimal non-contingent contract.

Lemma 1. *There exists a $\hat{p}_N \in (0.5, \bar{p}]$ such that for p below a cutoff $\hat{p}_N$, the prosecutor chooses $\hat{x}_S$ and the defendant is convicted after a testimony regardless of the signal. For p above this cutoff, the prosecutor chooses $\min\{\hat{x}_R, \bar{x}\}$ and the defendant is only convicted after a testimony and signal G.*

Given this lemma, we can now characterize the size of the type 1 and type 2 errors under the choice of the prosecutor,

$$E_1 = \begin{cases} \hat{x}_S - k & \text{for } 0.5 < p < \hat{p}_N \\ (\hat{x}_R - k)(1-p) & \text{for } \hat{p}_N < p \leq \bar{p} \\ (\bar{x} - k)(1-p) & \text{for } \bar{p} < p \leq \bar{\bar{p}} \end{cases}$$

$$E_2 = \begin{cases} 1 - \hat{x}_S & \text{for } 0.5 < p < \hat{p}_N \\ 1 - p\hat{x}_R & \text{for } \hat{p}_N < p \leq \bar{p} \\ 1 - p\bar{x} & \text{for } \bar{p} < p \leq \bar{\bar{p}} \end{cases}$$

A numeric example

Let $\lambda = 0.5$, $\beta_0 = 0.8$, $k = 0.1$, $\bar{x} = 1$. Note that in this case, for $\bar{p} \approx 0.782609$ and $\bar{\bar{p}} = 0.8$.

$$\Pi_S(\hat{x}_S) = \hat{x}_S - (1-\lambda)k = \frac{0.1}{1 - \frac{1}{4}\frac{1-p}{p}} - 0.05$$

$$\Pi_R(\hat{x}_R) = 0.5\hat{x}_R - 0.5(1-p)k = \frac{0.05}{1 - \frac{1}{4}\frac{p}{1-p}} - 0.05(1-p)$$

Setting these two payoffs equal gives the cutoff $\hat{p}_N \approx 0.62670$, below which it is better for the prosecutor to select $\hat{x}_S$ and above which it is better for the prosecutor to select $\hat{x}_R$.

When the additional evidence is not very informative, the best the prosecutor can do is to pursue the safe strategy by using the lying cost (penalty for perjury or the difficulty to fabricate a story) as a screening device to meet the burden of proof. Here, the loss of convictions from unfavorable additional evidence outweighs the fact that probability the witness agrees to testify is greater because the prosecutor can pay more. When the additional evidence is more informative, however, the prosecutor would have to further restrict leniency to get conviction when the additional evidence is unfavorable. But, the prosecutor could greatly increase leniency and still get conviction under a favorable additional evidence, resulting in a lot more convictions, so the prosecutor gets more convictions under a risky strategy.

4. Contingent contract is allowed

Following a contingent contract, if the testimony will result in a conviction regardless of the signal, then the contingent contract is equivalent to a non-contingent contract. Thus, when we refer to a contingent contract, we mean a contingent contract that results in a guilty verdict only if the signal is favorable to the prosecutor. Thus, there are no contingent offers in this sense with $x < \hat{x}_S$.

Consider a contingent contract that gives rise to an equilibrium where CTB (testimony under a contingent contract with an unfavorable signal) does not generate a posterior probability of guilt sufficient for conviction, but CTG (testimony under a contingent contract with a favorable signal) is does. Then, the witness will believe they will only receive the offered leniency x if the signal is favorable (G). Thus, the expected gross payoff of a witness who is telling the truth is px while the expected payoff of a witness who is not is $(1-p)x-k$. Because the cost of testimony is uniformly distributed, these are the ex ante probabilities of testimony given an offer of leniency x in this equilibrium. As a result, the posterior probabilities after the unfavorable (B) and favorable (G) signals in this equilibrium are given by:

$$\beta_{CTG} = \frac{\lambda x p^2}{\lambda x p^2 + (1-\lambda)((1-p)x-k)(1-p)}$$

$$\beta_{CTB} = \frac{\lambda x p(1-p)}{\lambda x p(1-p) + (1-\lambda)((1-p)x-k)p}$$

Note that if $x < \frac{k}{1-p}$, $\beta_{CTB} = 1 > \beta_0$, so this type of subgame equilibrium will not exist

if $x < \frac{k}{1-p}$. Define the payment $\hat{x}_m$ by

$$\hat{x}_m = \frac{k}{(1-p)-\theta(1-p)}$$

This is derived from $\beta_{CTB}(\hat{x}_m) = \beta_0$. That is, when payment is below or equal to this cutoff, a testimony and a bad signal together can convict.

Define the payment $\hat{x}_C$ by

$$\hat{x}_C = \begin{cases} \frac{k}{(1-p)-\theta\frac{p^2}{1-p}} & \text{for } p \leq \dot{p} \\ \infty & \text{for } p > \dot{p} \end{cases}$$

where $\dot{p}$ is defined by:

$$\frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda} = \theta = \frac{(1-\dot{p})^2}{\dot{p}^2}$$

This cutoff $\hat{x}_C$ is derived from $\beta_{CTG}(\hat{x}_C) = \beta_0$ for $p \leq \dot{p}$. That is, for any given signal accuracy (p), there is a maximum leniency payment such that the posterior probability of guilt after observing the favorable signal and testimony is large enough to convict. The more accurate the signal (the larger is p), the larger the leniency payment can be and still convict when the signal is favorable. The reason for this is that when the signal is more accurate, a favorable signal is more effective at establishing guilt even though the larger payment will make the testimony less effective at establishing guilt (because it will induce more dishonest testimony). When $p > \dot{p}$, any contingent payment is credible when there is also a good signal because

$$p > \dot{p} \Rightarrow \theta > \frac{(1-p)^2}{p^2} \Rightarrow \beta_{CTG} > \frac{\lambda p^2}{\lambda p^2 + (1-\lambda)(1-p)^2} > \beta_0$$

It follows that:

$$\hat{x}_C > \hat{x}_m > \frac{k}{1-p}$$

That is, the maximum leniency that can sustain a conviction under a contingent contract is greater when the signal is favorable than when the signal is unfavorable, and the maximum leniency that can sustain a conviction under a contingent contract with an unfavorable signal exceeds lying cost divided by the probability of an innocent defendant receiving a favorable (for the prosecutor) signal.

Therefore, we have the following lemma:

Lemma 2. *For a contingent contract with $x \in (\hat{x}_m, \hat{x}_C]$, there exists a subgame equilibrium where the testimony leads to a conviction if the signal is favorable to the prosecutor, and to no conviction if the signal is not favorable.*

We would like $\hat{x}_m$ to be sufficiently small relative to the maximum feasible payment $\bar{x}$, so that there is always a range of contingent payment for which there exists the above subgame equilibrium where a testimony and a good signal G are both needed to land a conviction. Because $\hat{x}_m = \frac{k}{(1-p)(1-\theta)}$ we have a sufficient condition for this that holds for all $p < 1/(1+\theta)$:

Assumption 2'. *The lying cost is sufficiently small:*

$$\frac{k}{\bar{x}} < \frac{\theta(1-\theta)}{1+\theta}, \text{ with } \theta = \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}$$

Note that Assumption 2' implies Assumption 2. Also, note that even if lying costs are not so small, if the signal is somewhat less accurate, we can still get a contingent leniency equilibrium in which conviction requires the favorable signal for slightly larger lying costs. For example, if $\lambda = 1/2, \beta_0 = 9/10$ then $\theta = 1/9$ which means that Assumption 2' implies $\frac{k}{\bar{x}} < 4/45 \simeq 0.089$. But, if $p = 3/4 << \frac{1}{1+\theta}$, then we only need $\frac{k}{\bar{x}} < (1-p)(1-\theta) = 2/9 \simeq 0.22$, which is much less restrictive.

For a contingent offer in a middle range with $x \in (\hat{x}_S, \hat{x}_m)$, there is no subgame equilibrium where CTG can convict for sure but CTB cannot for sure. This is because then, because $x < \hat{x}_m$, a lying witness will not testify or testify with such tiny probability that CTB is credible enough to convict, which reaches a contradiction. In this range, there is no subgame equilibrium where CTG and CTB both lead to a conviction for sure either. This is because then $x > \hat{x}_S$ implies that CTB is not credible enough to convict, which reaches a contradiction as well. Then the only subgame equilibrium is where the jury randomizes on conviction when seeing CTB. Let $q(x)$ be the probability of conviction after CTB. It satisfies:

$$\frac{\lambda x(p+(1-p)q)(1-p)}{\lambda x(p+(1-p)q)(1-p)+(1-\lambda)((1-p+pq)x-k)p} = \beta_0$$

That is,

$$q(x) = \frac{k - \left(1 - \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}\right)(1-p)x}{\left(1 - \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}\frac{(1-p)^2}{p^2}\right)px}$$

Note that $q(x)$ is strictly decreasing in x with $q(\hat{x}_S) = 1$ and $q(\hat{x}_m) = 0$ by the definition of $\hat{x}_m$. The prosecutor's payoff from this equilibrium is:

$$\Pi_m = \lambda(p + (1-p)q(x))^2 x + (1-\lambda)((1-p+pq(x))x - k)(1-p+pq(x))$$

Because $\Pi_m(x)$ is strictly convex in x (shown in the Appendix), $\Pi_m(\hat{x}_S) = \Pi_S(\hat{x}_S)$, $\Pi_m(\hat{x}_m) = \Pi_C(\hat{x}_m)$, and $\hat{x}_m < \bar{x}$, the optimal x is not in the interior range of $(\hat{x}_S, \hat{x}_m)$ that gives rise to mixed strategy of the jury.

Because $p > 0.5$, we have:

Lemma 3.

$$k < \hat{x}_S < \hat{x}_R < \hat{x}_C$$

If the contract is contingent, the prosecutor's payoff is:

$$\begin{cases} \lambda x & \text{for } x \leq k \\ \Pi_S(x) & \text{for } x \in (k, \hat{x}_S] \\ \Pi_m(x) & \text{for } x \in (\hat{x}_S, \hat{x}_m] \\ \Pi_C(x) & \text{for } x \in (\hat{x}_m, \min\{\hat{x}_C, \bar{x}\}] \\ 0 & \text{otherwise.} \end{cases}$$

where

$$\Pi_C(x) \equiv \lambda p^2 x + (1-\lambda)((1-p)x - k)(1-p)$$

The first term in this payoff reflects the conviction probability due to the defendant being guilty (probability λ), times the witness agreeing to testfy (probability px because that is the expected leniency benefit from testimony and the testimony cost is uniformly distributed), times the probability of getting the favorable signal when the defendant is guilty (p). The second term is the conviction probability when the defendant is innocent (probability $1-\lambda$), times the witness agreeing to testfy (probability $(1-p)x - k$ because that is the expected leniency benefit from testimony less the lying costs and the testimony cost is uniformly distributed), times the probability of getting the favorable signal when the defendant is innocent $(1-p)$.

If leniency is less than the lying cost, then only honest witnesses testify and conviction occurs whenever the defendant is guilty and the honest witness agrees to testify (their

cost of testifying is less than the leniency benefit). If x is a little larger than k, there will be some dishonest witnesses testifying, but not enough to prevent testimony alone from guaranteeing conviction, even with the unfavorable signal. But, as the leniency payment gets even larger, we enter the range of the mixed strategy equilibrium in which the jury convicts for sure with a good signal but mixes between conviction and acquittal for the bad signal. Then, for an even larger contingent payment, the jury will only convict with a favorable signal because of the increased probability of a dishonest witness. If the leniency payment is too large, however, then because the favorable signal alone is not enough to convict without some added evidence from witness testimony, the witness testimony credibility will be sufficiently weak that the jury will acquit even with the favorable signal.

The following lemma compares the prosecutor's payoff between a contingent contract and a non-contingent risky one.

Lemma 4. *Let $\underline{p}$ be defined by $\hat{x}_C(\underline{p}) = \bar{x}$, and recall that $\bar{p}$ be defined by $\hat{x}_R(\bar{p}) = \bar{x}$. There is a unique cutoffs $\tilde{p} \in (\underline{p}, \bar{p})$ such that*

1. *For $p < \underline{p}$, $\Pi_C(\min\{\hat{x}_C, \bar{x}\}) = \Pi_C(\hat{x}_C) > \Pi_R(\hat{x}_R) = \Pi_R(\min\{\hat{x}_R, \bar{x}\})$.*
2. *For $p \in (\underline{p}, \tilde{p})$, $\Pi_C(\min\{\hat{x}_C, \bar{x}\}) = \Pi_C(\bar{x}) > \Pi_R(\hat{x}_R) = \Pi_R(\min\{\hat{x}_R, \bar{x}\})$.*
3. *For $p \in (\tilde{p}, \bar{p})$, $\Pi_C(\min\{\hat{x}_C, \bar{x}\}) = \Pi_C(\bar{x}) < \Pi_R(\hat{x}_R) = \Pi_R(\min\{\hat{x}_R, \bar{x}\})$.*
4. *For $p > \bar{p}$, $\Pi_C(\min\{\hat{x}_C, \bar{x}\}) = \Pi_C(\bar{x}) < \Pi_R(\bar{x}) = \Pi_R(\min\{\hat{x}_R, \bar{x}\})$.*

The proof of this lemma is in the Appendix. The cutoff $\underline{p}$ is where $\bar{x}$ starts to bind on $\hat{x}_C$ for a contingent contract, whereas $\bar{p}$ is where $\bar{x}$ starts to bind on $\hat{x}_R$ for a non-contingent risky contract. When $\bar{x}$ is not binding on either of them (the first case in Lemma 4), the prosecutor's payoff of a contingent contract is always greater than that of a non-contingent risky contract because the contingent contract is relatively more attractive to an honest witness than a dishonest witness. If neither payment is externally constrained, this means that the contingent contract can be set to attract a higher overall probability of witness testimony while still achieving the same posterior probability of guilt given the favorable signal as the non-contingent risky contract. When $\bar{x}$ is binding on both of them (the last case in Lemma 4), the payoff of a contingent contract is always less than that of a non-contingent risky contract because the expected leniency benefit to the witness is smaller under the contingent contract (both contracts provide the same level leniency but the witness only receives it for sure under the non-contingent contract). In between these two cases, there is a unique cutoff $\tilde{p}$ at which the two payoffs are equal.

The next lemma deals with the comparison between a contingent contract and a non-

contingent safe one. The payoff of a non-contingent safe contract is decreasing in p because to make signal B credible to convict under a more precise signal, the prosecutor has to reduce the payment, which reduces the witness's participation. There is no direct effect from p on the witness's payoff from testifying because they are paid regardless of which signal realizes. On the other hand, the payoff of a contingent contract is strictly increasing in p.

Lemma 5. *There is a unique solution $\hat{p}_C$ to $\Pi_S(\hat{x}_S) = \Pi_C(\min\{\hat{x}_C, \bar{x}\})$ such that for $p < \hat{p}_C$, $\Pi_S(\hat{x}_S) > \Pi_C(\min\{\hat{x}_C, \bar{x}\})$ and for $p > \hat{p}_C$, $\Pi_S(\hat{x}_S) < \Pi_C(\min\{\hat{x}_C, \bar{x}\})$.*

This lemma is proved in the Appendix. Lemma 4 and Lemma 5 together imply:

Proposition 1. *When $\hat{p}_C < \tilde{p}$, there are three parameter cases of p. For $p < \hat{p}_C$, the prosecutor chooses a non-contingent safe contract with $x = \hat{x}_S$. For $p \in (\hat{p}_C, \tilde{p})$, the prosecutor chooses a contingent contract with $x = \min\{\hat{x}_C, \bar{x}\}$. For $p > \tilde{p}$, the prosecutor chooses a non-contingent risky contract with $x = \min\{\hat{x}_R, \bar{x}\}$.*

When $\hat{p}_C \geq \tilde{p}$, the prosecutor never uses a contingent contract.

Proof. By an abuse of notation, let $\Pi_R(x, p)$ denote the non-contingent risky payoff as a function of both x and p. It is strictly increasing in p because $\lambda > 0.5$. It is also strictly increasing in x, and $\hat{x}_R$ is strictly increasing in p. Therefore, $\Pi_R(\min\{\hat{x}_R, \bar{x}\})$ is strictly increasing in p. Similarly, $\Pi_C(\min\{\hat{x}_C, \bar{x}\})$ is strictly increasing in p. The two payoffs single cross at $\tilde{p}$ with $\Pi_R(\min\{\hat{x}_R, \bar{x}\}) < \Pi_C(\min\{\hat{x}_C, \bar{x}\})$ for $p < \tilde{p}$.

Case 1. $\hat{p}_C < \tilde{p}$. For $p < \hat{p}_C$, $\Pi_S(\hat{x}_S) > \Pi_C(\min\{\hat{x}_C, \bar{x}\}) > \Pi_R(\min\{\hat{x}_R, \bar{x}\})$, so a non-contingent safe contract is the best. For $p \in (\hat{p}_C, \tilde{p})$, $\Pi_C(\min\{\hat{x}_C, \bar{x}\}) > \Pi_S(\hat{x}_S)$ and $\Pi_C(\min\{\hat{x}_C, \bar{x}\}) > \Pi_R(\min\{\hat{x}_R, \bar{x}\})$, so a contingent contract is the best. For $p > \tilde{p}$, $\Pi_R(\min\{\hat{x}_R, \bar{x}\}) > \Pi_C(\min\{\hat{x}_C, \bar{x}\}) > \Pi_S(\hat{x}_S)$, so a non-contingent risky contract is the best.

Case 2. $\hat{p}_C \geq \tilde{p}$. Then $\hat{p}_N \in [\tilde{p}, \hat{p}_C]$ and $\Pi_C(\min\{\hat{x}_C, \bar{x}\})$ is never the highest payoff among the three payoffs for any p. ∎

That is, potentially for a middle range of p, the prosecutor's payoff is greatest from choosing a contingent contract. This is illustrated in the following figure using a numeric example.

The prosecutor is essentially picking among three options: non-contingent safe, contingent, and non-contingent risky. Figure 1 shows that for a middle range of values of p

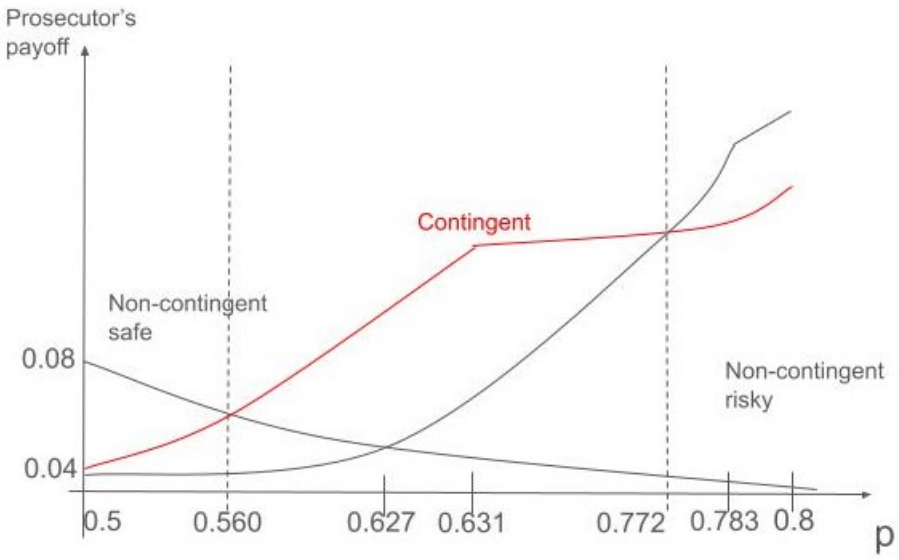


Figure 1. The payoffs when contingency is allowed for the numeric example with $\lambda = 0.5$, $\beta_0 = 0.8$, $k = 0.1$ and $\bar{x} = 1$.

(bounded by the dotted vertical lines), the highest payoff is attained with a contingent contract. Within this range, for lower p, $\bar{x}$ is not binding so the prosecutor chooses a payment that hits the credibility constraint. For higher p within this range, $\bar{x}$ is binding, the payoff of a contingent contract increases less rapidly with p.

The advantage of a contingent contract, relative to non-contingent contracts, is that screening increases the credibility of the testimony and allows the credibility constraint to be relaxed, so the prosecutor can pay more (and more so for a stronger external signal, i.e., a higher p) and still maintain the credibility of a testimony. The drawback of a contingent contract is that the witness is only paid when the signal is good, so the witness is less motivated to testify facing the uncertainty, so the contingent contracts loses to non-contingent ones for very low or very high p.

5. Type 1 and type 2 errors

When contingent contract is allowed, the following expressions show the chances of type 1 (innocent conviction) and type 2 (guilty acquittal) errors for different values of p in the most rich parameter case ($\hat{p}_C < \underline{p}$). Here, "non-binding" means that the maximum upper

bound $\bar{x}$ is not binding on the payment.

$$E_1 = \begin{cases} \hat{x}_S - k & \text{for } 0.5 < p \leq \hat{p}_C \text{ (non-contingent safe)} \\ ((1-p)\hat{x}_C - k)(1-p) & \text{for } \hat{p}_C < p \leq \underline{p} \text{ (contingent, non-binding)} \\ ((1-p)\bar{x} - k)(1-p) & \text{for } \underline{p} < p \leq \tilde{p} \text{ (contingent, binding)} \\ (\hat{x}_R - k)(1-p) & \text{for } \tilde{p} < p \leq \bar{p} \text{ (non-contingent risky, non-binding)} \\ (\bar{x} - k)(1-p) & \text{for } \bar{p} < p \leq \bar{\bar{p}} \text{ (non-contingent risky, binding)} \end{cases}$$

$$E_2 = \begin{cases} 1 - \hat{x}_S & \text{for } 0.5 < p \leq \hat{p}_C \text{ (non-contingent safe)} \\ 1 - p^2\hat{x}_C & \text{for } \hat{p}_C < p \leq \underline{p} \text{ (contingent, non-binding)} \\ 1 - p^2\bar{x} & \text{for } \underline{p} < p \leq \tilde{p} \text{ (contingent, binding)} \\ 1 - p\hat{x}_R & \text{for } \tilde{p} < p \leq \bar{p} \text{ (non-contingent risky, non-binding)} \\ 1 - p\bar{x} & \text{for } \bar{p} < p \leq \bar{\bar{p}} \text{ (non-contingent risky, binding)} \end{cases}$$

Notice that type 1 errors are chances of convictions and type 2 errors are chances of acquittals, so the prosecutor wants to maximize type 1 errors and minimize type 2 errors. The following result (proved in the Appendix) confirms a common concern about contingent contract: it may increase innocent conviction.

Proposition 2. *When the prosecutor chooses a contingent contract with payment strictly below $\bar{x}$, type 1 error (innocent conviction) is increased by the contingency.*

This result is more subtle than it appears to be. This result says not only the payment is higher under the contingent contract, but it is so high that after taking into account the lower chance of receiving it, a dishonest type expects to get paid more under the contingent contract than under the non-contingent one. To understand this, take the case where the prosecutor chooses contingent contract over a non-contingent risky one when contingency is allowed. This implies that the posterior beliefs β_{NTG} and β_{CTG} are equal. That is, the likelihood ratio of liars over truth tellers are equal:

$$\frac{\hat{x}_R - k}{\hat{x}_R} = \frac{(1-p)\hat{x}_C - k}{p\hat{x}_C}$$

This is equivalent to:

$$1 - \frac{k}{\hat{x}_R} = \frac{1-p}{p} - \frac{k}{p\hat{x}_C}$$

The contingent contract's likelihood ratio is reduced by its screening power: $\frac{1-p}{p} < 1$. The lying cost k is better at reducing the likelihood ratio if the expected payment to the honest witness is smaller. Then the expected payment to the honest type must be higher under the contingent contract for both contingent and non-contingent risky contract to have the same likelihood ratio:

$$p\hat{x}_C > \hat{x}_R$$

Given that the expected payment for the honest type is higher, the expected payment to the dishonest type must be higher too to maintain the same likelihood ratio.

In the legal case United State v. Waterman, the witness Gamst was sentenced to 12 years in prison prior to reaching the agreement with the prosecutor. Proposition 2 suggests that in that case the contingent agreement between the prosecutor and the witness Gamst likely increased the type 1 error against the defendant Waterman. This proposition also provides a rationale for the A.B.A. standards which prohibits contingency for expert witnesses, but not fact witnesses. Fact witnesses, such as Gamst, are usually accomplices, so the prosecutor faces a natural upper bound on payment – their legal liabilities. Expert witnesses do not have this upper bound. We have shown that when there is no upper bound, type 1 error is for sure higher with contingency.

Our next result is more surprising. It says that it is possible that allowing contingent leniency could increase both types of errors, including the error of guilty acquittal.

Proposition 3. *When $\bar{x}$ is sufficiently high, there exists values of p for which type 1 and type 2 errors both increase when contingency is allowed.*

Proof. Note that $\underline{p}$ is increasing in $\bar{x}$, so for sufficiently large $\bar{x}$, $\hat{p}_C < \underline{p}$. That is, the payoff of non-contingent safe contract is equal to the payoff of the contingent contract when $\bar{x}$ is not binding on the contingent contract's payment. Let the superscripts denote the type of the contract.

Consider p sufficiently close to $\hat{p}_C$ from above. This is when the prosecutor chooses the contingent contract with $x = \hat{x}_C$. At $p = \hat{p}_C$, the payoff of the non-contingent contract and the contingent one are the same:

$$\lambda(1-E_2^S)+(1-\lambda)E_1^S = \lambda(1-E_2^C)+(1-\lambda)E_1^C$$

By the proof of Proposition 2, $E_1^S < E_1^C$ (type 1 error is higher under contingency) for

$p = \hat{p}_C$, then, we must have for $p = \hat{p}_C$,

$$E_2^S < E_2^C$$

Then, this is also true for p sufficiently close to $\hat{p}_C$ from above because of the continuity of the errors in p. ■

The intuition is that the prosecutor prefers a higher type 1 error and a lower type 2 error. Sometimes, the prosecutor will benefit so much from a jump in the type 1 error from adopting a contingent contract that he is willing to tolerate a higher type 2 error under the contingent contract.

This only happens when the prosecutor chooses a contingent contract over a non-contingent safe contract, because otherwise, to maintain the credibility of the testimony with a good signal the two errors have to go in the opposite direction. However, here the prosecutor only has to maintain credibility of a testimony together with a good signal with a contingent contract, but with a non-contingent safe contract, the prosecutor has to maintain credibility of a testimony together with a bad signal. One can write the binding credibility constraint of non-contingent safe contract and the contingent contract in terms of the errors. Let the superscripts denote the type of the contract.

$$\frac{\lambda(1-E_2^S)(1-p)}{\lambda(1-E_2^S)(1-p)+(1-\lambda)E_1^S p} = \frac{\lambda(1-E_2^C)}{\lambda(1-E_2^C)+(1-\lambda)E_1^C} = \beta_0$$

Here, when type 1 error is higher for the contingent risky contract ($E_1^S < E_1^C$), it has to be that $(1-E_2^S)\frac{1-p}{p} < 1-E_2^C$, but it is possible for $1-E_2^S > 1-E_2^C$. That is, type 2 error might be higher with the contingent risky contract.

On the other hand, if the leniency constraint is binding on the prosecutor for contingent leniency, but that constraint does not bind for non-contingent leniency, then it is possible for contingency to decrease both type 1 and type 2 errors, as the next proposition shows.

Proposition 4. *When $\bar{x}$ is sufficiently high, there exists a range of p for which both type 1 and type 2 errors decrease when contingency is allowed. This happens only when the prosecutor hits the upper bound of $\bar{x}$ with the contingent payment.*

Proof. When $\bar{x} > \max\{\hat{x}_C(\hat{p}_C), \hat{x}_R(\tilde{p})\}$, the prosecutor chooses the contingent contract over the non-contingent risky one for p close to $\tilde{p}$ from below. When p is sufficiently close to

$\tilde{p}$, the best payment for a contingent risky contract is $x = \bar{x}$.

At $p = \tilde{p}$, $\hat{x}_C > \bar{x}$ and $\hat{x}_R < \bar{x}$:

$$\frac{\lambda(1-E_2^C)}{\lambda(1-E_2^C)+(1-\lambda)E_1^C} > \beta_0 = \frac{\lambda(1-E_2^R)}{\lambda(1-E_2^R)+(1-\lambda)E_1^R}$$

Note that at $p = \tilde{p}$, the payoffs are the same (which are the denominator of the posteriors above), so the numerator of the posterior must be bigger under the contingent contract:

$$\lambda(1-E_2^C) > \lambda(1-E_2^R) \Rightarrow E_2^C < E_2^R$$

That is, the type 2 error is smaller under the contingent one. Then, equal payoffs imply that at $p = \tilde{p}$:

$$\lambda(1-E_2^C)+(1-\lambda)E_1^C = \lambda(1-E_2^R)+(1-\lambda)E_1^R \Rightarrow E_1^C < E_1^R$$

Because payoff $\Pi_C(\bar{x})$ and $\Pi_R(\hat{x}_R)$ are continuous in p at $p = \tilde{p}$, these rankings of errors hold true for p sufficiently close to $\tilde{p}$ from below, where the prosecutor chooses the contingent risky contract. ■

The screening ability of a contingent contract allows the prosecutor to raise the payment to the witness and still maintain credibility of the testimony. The upper bound on the contingent payment forces the contingent contract to be more credible than necessary to convict and reduces the innocent conviction rate. The higher rate of guilty conviction gives the prosecutor incentive to pick the contingent contract even when the innocent conviction rate is lower than the alternative non-contingent risky contract.

A numeric example

Continue the above example: $\lambda = 0.5$, $\beta_0 = 0.8$, $k = 0.1$, $\bar{x} = 1$.

$$\hat{x}_C = \bar{x} \Rightarrow \underline{p} \approx 0.63071$$

$$\Pi_C(\hat{x}_C) = 0.5p^2\hat{x}_C + 0.5(1-p)^2\hat{x}_C - 0.5(1-p)k = (p^2+(1-p)^2)\frac{0.05}{1-p-\frac{1}{4}\frac{p^2}{1-p}} - (1-p)0.05$$

Then,

$$\Pi_C(\hat{x}_C) = \Pi_S(\hat{x}_S) \Rightarrow \hat{p}_C \approx 0.559571$$

$$\Pi_C(\bar{x}) = \Pi_R(\hat{x}_R) \Rightarrow \tilde{p} \approx 0.77182$$

The payment choice when contingency is allowed is:

$$x^C = \begin{cases} \hat{x}_S = \frac{0.1}{1-\frac{1}{4}\frac{1-p}{p}} & \text{for } 0.5 < p \leq 0.559571 \\ \hat{x}_C = \frac{0.1}{1-p-\frac{1}{4}\frac{p^2}{1-p}} & \text{for } 0.559571 < p \leq 0.63071 \\ \bar{x} = 1 & \text{for } 0.63071 < p \leq 0.77182 \\ \hat{x}_R = \frac{0.1}{1-\frac{1}{4}\frac{p}{1-p}} & \text{for } 0.77182 < p \leq 0.782609 \\ \bar{x} = 1 & \text{for } 0.782609 < p \leq 0.8 \end{cases}$$

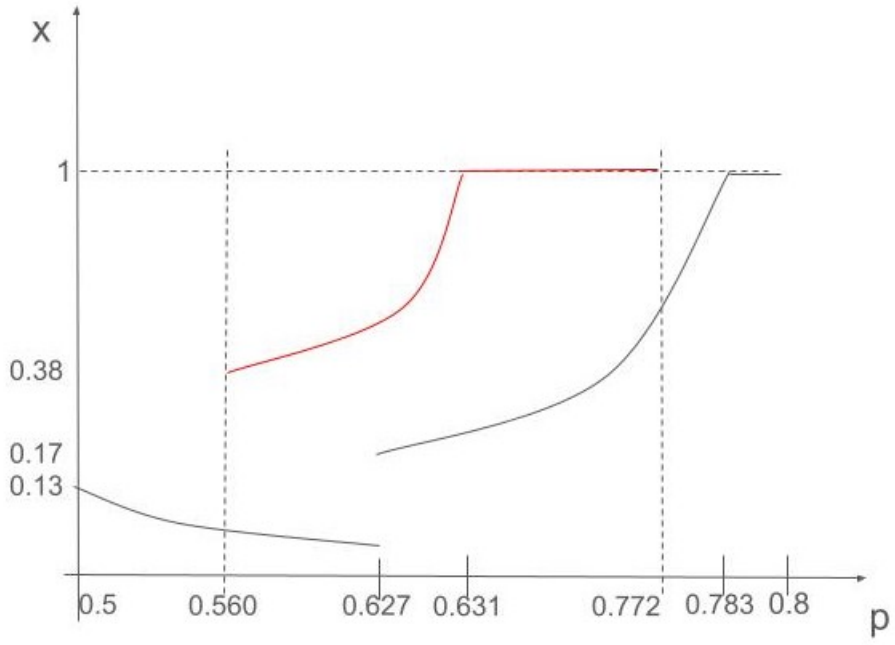


Figure 2. The payment choice when contingency is allowed for the numeric example.

The curve in the black ink is the optimal non-contingent payment. It is decreasing in p for the lower p where non-contingent safe strategy is better than the risky strategy and is increasing in p for larger p where the risky strategy is better than the safe strategy. The red line in this figure is the prosecutor's optimal payment choice for a contingent risky contract. It replaces the corresponding lower non-contingent payment when contingency is allowed

(between the vertical dotted lines). The contingent payment is strictly increasing in p until it hits the upper bound.

Next we examine the numeric example's type 1 error of innocent conviction when contingency is allowed.

$$E_1^C = \begin{cases} \hat{x}_S - k = \frac{0.1}{1-\frac{1}{4}\frac{1-p}{p}} - 0.1 & \text{for } 0.5 < p \leq 0.559571 \\ ((1-p)\hat{x}_C - k)(1-p) = \left(\frac{0.1(1-p)}{1-p-\frac{1}{4}\frac{p^2}{1-p}} - 0.1\right)(1-p) & \text{for } 0.559571 < p \leq 0.63071 \\ ((1-p)\bar{x} - k)(1-p) = (1-p-0.1)(1-p) & \text{for } 0.63071 < p \leq 0.77182 \\ (\hat{x}_R - k)(1-p) = \left(\frac{0.1}{1-\frac{1}{4}\frac{p}{1-p}} - 0.1\right)(1-p) & \text{for } 0.77182 < p \leq 0.782609 \\ (\bar{x} - k)(1-p) = 0.9(1-p) & \text{for } 0.782609 < p \leq 0.8 \end{cases}$$

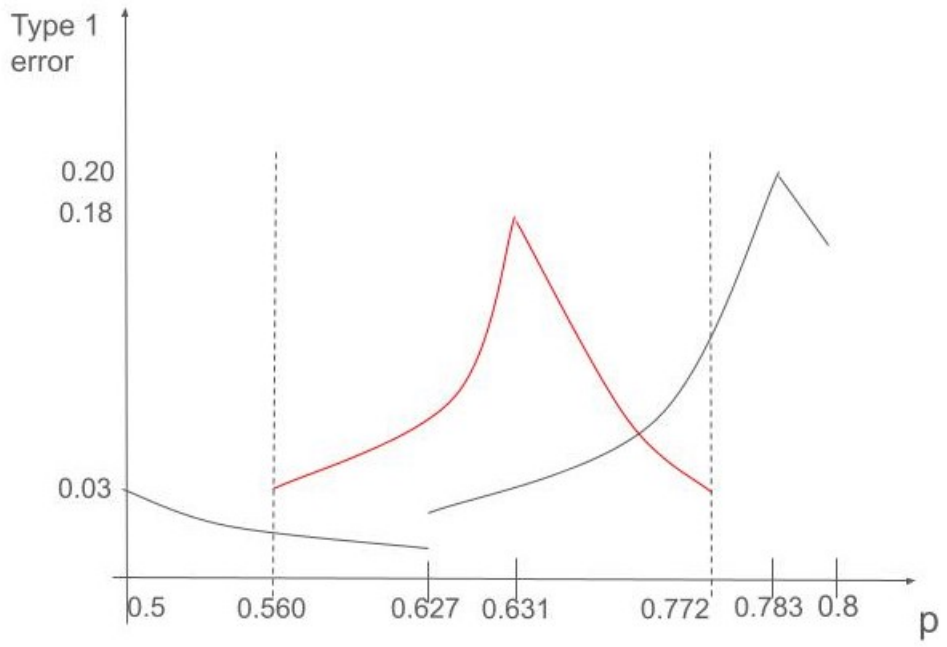


Figure 3. The type 1 error of innocent conviction when contingency is allowed for the numeric example.

Figure 3 plots the type 1 error. This figure shows that when p is just below the cutoff 0.772, type 1 error is lower with the contingent contract (the red line) than with the non-contingent contract (the black line), as shown in Proposition 4. Below is the type 2 error

when contingency is allowed.

$$E_2^C = \begin{cases} 1-\hat{x}_S = 1-\frac{0.1}{1-\frac{1}{4}\frac{1-p}{p}} & \text{for } 0.5 < p \leq 0.559571 \\ 1-p^2\hat{x}_C = 1-p^2\frac{0.1}{1-p-\frac{1}{4}\frac{p^2}{1-p}} & \text{for } 0.559571 < p \leq 0.63071 \\ 1-p^2\bar{x} = 1-p^2 & \text{for } 0.63071 < p \leq 0.77182 \\ 1-p\hat{x}_R = 1-\frac{0.1p}{1-\frac{1}{4}\frac{p}{1-p}} & \text{for } 0.77182 < p \leq 0.782609 \\ 1-p\bar{x} = 1-p & \text{for } 0.782609 < p \leq 0.8 \end{cases}$$

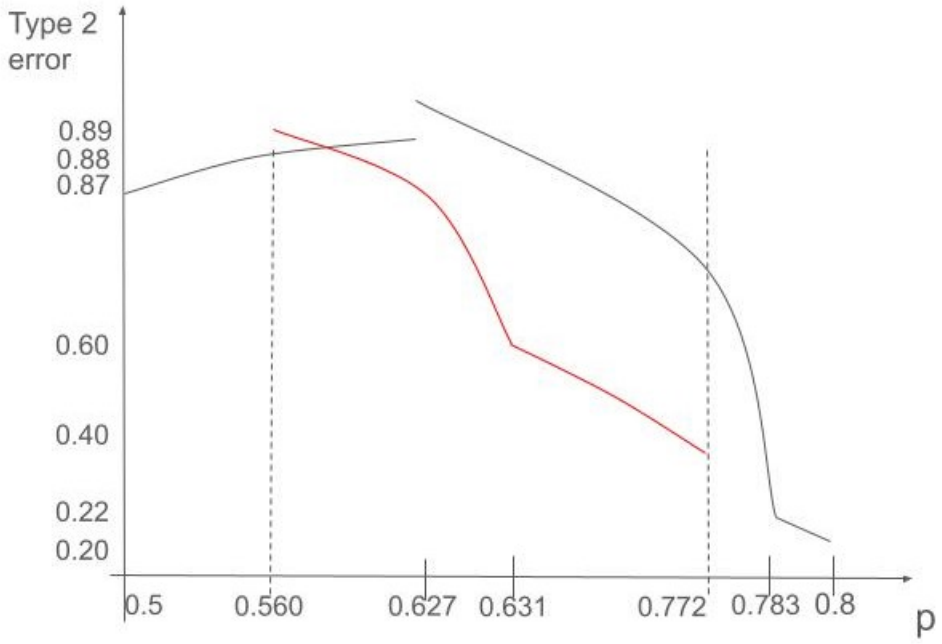


Figure 4. The type 2 error of guilty acquittal when contingency is allowed for the numeric example.

Figure 4 plots this type 2 error. It shows that when p is just above the cutoff 0.560, type 2 error is higher with the contingent contract (the red line) than with the non-contingent contract (the black line), as shown in Proposition 3.

The next proposition shows that contingency can only reduce both types of errors if the maximum allowable leniency is not too large. Recall that $\hat{p}_N$is the accuracy of the signal for which the prosecutor is indifferent between the non-contingent safe contract and the non-contingent risky contract.

Proposition 5. *For any $p \geq \min\{\hat{p}_N, (\sqrt{5}-1)/2)$, there is an $\bar{x}(p)$ on the contingent payment under which allowing contingency reduces undesirable innocent conviction and increases desirable guilty conviction.*

Proof. Case 1. For $p > \hat{p}_N$, the prosecutor chooses a non-contingent risky contract when contingency is banned. Consider $\bar{x} = \frac{\hat{x}_R}{1-p}$. Note that $\hat{x}_C > \frac{\hat{x}_R}{1-p} = \bar{x}$, so such a restriction is binding on a contingent contract, so the prosecutor chooses $x = \frac{\hat{x}_R}{1-p}$ when offering a contingent contract. At the same time, because $\bar{x} = \frac{\hat{x}_R}{1-p} > \hat{x}_R$, the prosecutor chooses $\hat{x}_R$ when offering a non-contingent contract. Then, type 1 error of the contingent contract is $E_1^C = ((1-p)\frac{\hat{x}_R}{1-p} - k)(1-p) = ((1-p)\hat{x}_R - k)(1-p) = E_1^R$. Type 2 error of the contingent contract is $E_2^C = 1 - p^2\frac{\hat{x}_R}{1-p} < 1 - p\hat{x}_R = E_2^R$ because $p > 0.5$. That is, under this upper bound, contingency reduces type 2 error while keeping type 1 error the same. Then any upper bound slightly below this level will reduce both errors.

Case 2. For $p < \hat{p}_N$, the prosecutor chooses a non-contingent safe contract when contingency is banned. Consider $\bar{x} = \frac{\hat{x}_S}{1-p}$. Note that $\hat{x}_S > k$ implies $\bar{x} > \frac{k}{1-p}$ and $p > 0.5$ implies $\bar{x} < \hat{x}_C$, so the prosecutor chooses $x = \bar{x} = \frac{\hat{x}_S}{1-p}$ for a contingent contract. If $\frac{p^2}{1-p} > 1$ ($p > (\sqrt{5}-1)/2 \approx 0.618$), then $p^2\frac{\hat{x}_S}{1-p} > \hat{x}_S$, so type 2 error decreases with contingency. Further, $\hat{x}_S > k$ implies

$$(1-p)\hat{x}_S + pk < \hat{x}_S \Rightarrow (1-p)^2\bar{x} - k(1-p) < \hat{x}_S - k$$

That is, type 1 error also decreases with contingency. ∎

These last two results suggest that if it is properly regulated through setting $\bar{x}$, contingent leniency can be socially desirable. Of course, to determine the optimal cap on leniency, the regulator must know what the maximum offer the prosecutor would make in a non-contingent offer (the offer that just maintains the credibility of the witness testimony sufficiently to ensure conviction under either the safe or risky strategy). This requires knowing all the parameters of the model, which might be harder for a regulator to estimate accurately than the prosecutor. There is a second best alternative, however, that only requires knowledge of the accuracy of the trial signal, p.

To see this, consider the following regulation. The prosecutor can only offer non-contingent leniency of any $x < \bar{x}$. But, with probability r, the witness will instead be offered only a contingent contract with a leniency payment of $x/(1-p)$. If r were large, the prosecutor would have an incentive to choose x above the credibility constraint in order

to obtain a more privately optimal contingency contract. But, if r is not too large, doing so would sacrifice too many convictions (because any leniency offer above the credibility constraint would result in acquittal). As we have shown above, this contingent leniency contract will result in fewer type 1 and type 2 errors. In further drafts, we will explore both the maximal r that will work with this scheme and if providing the leniency contract as an option to the witness can improve things further by generating additional desirable screening.

6. Discussion

6.1. Costly payment

The leniency/payment given to the witness can be costly to the prosecutor. If this cost is not too large such that either the feasibility or the credibility constraint is still binding, the qualitative result of this paper stands. This cost does not change the trade-off between a contingent contract and a non-contingent safe contract because under both contracts the prosecutor only pays if there is a win. The contingent contract becomes more attractive to the prosecutor relative to a non-contingent risky contract because the prosecutor does not pay if there is a loss under a contingent contract.

6.2. Implicit contingency

There is a sense in the law literature that some level of leniency is implied in some plea bargain agreement even when the prosecutor never explicitly makes an offer of leniency. It is credible to some extent that the prosecutor will give leniency, especially when the outcome is favorable to the prosecutor because the prosecutor is a repeated player, who may need another witness in the future. The existence of such relational contract seems especially plausible when the witnesses are already in the jail and the leniency they receive is quite visible to other prisoners. Covey (2014) says: "Unlike most other types of evidence frequently used in criminal cases, jailhouse snitch testimony is often uniquely insulated from effective impeachment. This insulation exists in part because the incentives that jailhouse informants receive in exchange for cooperation are typically hidden. Prosecutors rarely negotiate explicit deals with jailhouse snitches prior to their testimony. Rather, prosecutors and snitches operate with a shared understanding that a snitch's positive performance will eventually be rewarded with tangible benefits." That is, the witness may believe that there is an minimum level of contingent payment even when the prosecutor does not offer

any contingent payment. The question still remains whether the jury is sufficiently aware of such relational contract between the prosecutor and witness. If the jury is aware of it and incorporates the same expectation of implicit contingency into their assessment of the witness credibility, then one can think of the non-contingent contract as having a small level of (implicit) contingency as well. This will reduce the contrast between a contingent and non-contingent contract identified in this paper. The literature is however concerned that the jury is not sufficiently aware of such implicit payments and will wrongly assess the credibility of the testimony as a result (e.g., Joy 2006).

7. Conclusion

This paper shows that allowing contingency does not necessarily increase innocent conviction as commonly believed. Also it does not necessarily present a trade-off between reducing innocent conviction and reducing guilty acquittal. Allowing contingency may cause a prosecutor to pursue a risky trial strategy that increases guilty acquittal as well as increasing the innocent conviction, to the society's detriment. On the other hand, when the prosecutor either faces a natural limit on the amount leniency he can offer or faces a limit exogenously imposed, allowing contingency can take advantage of the screening power of a contingent contract to reduce innocent conviction and increase guilty conviction, to the society's benefit.

Appendix

Proof for $\Pi_m(x)$ to be strictly convex in x.

Proof. Let $f(x) \equiv (1-p+pq(x))x$. Within this proof, use the following notations:

$$a \equiv 1 - \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}, \qquad b \equiv 1 - \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}\frac{(1-p)^2}{p^2}$$

Then, $a < b$ and

$$q(x) = \frac{k}{bpx} - \frac{a}{b}\frac{1-p}{p} \Rightarrow q'(x) = -\frac{k}{bpx^2} = -\frac{1}{x}\left(q(x) + \frac{a}{b}\frac{1-p}{p}\right)$$

$$f(x) = (1-p+pq(x))x = \left(1-\frac{a}{b}\right)(1-p)x + \frac{k}{b}$$

Therefore,

$$f'(x) = \left(1-\frac{a}{b}\right)(1-p) > 0$$

From $\beta_{CTB} = \beta_0$, we have:

$$(1-\lambda)(f(x)-k)p = \frac{1-\beta_0}{\beta_0}\lambda(p+(1-p)q(x))x(1-p) \Rightarrow$$
$$\lambda(p+(1-p)q(x))x = \frac{\beta_0}{1-\beta_0}\frac{p}{1-p}(1-\lambda)(f(x)-k)$$

Plugging this into the payoff $\Pi_m(x)$, we have:

$$\Pi_m(x) = \frac{1-\lambda}{1-\beta_0}(f(x)-k)\left[\frac{\beta_0 p^2 + (1-\beta_0)(1-p)^2}{1-p} + pq(x)\right]$$

Therefore, the first order derivative of $\Pi_m(x)$ has the same sign as:

$$f'(x)\left[\frac{\beta_0 p^2 + (1-\beta_0)(1-p)^2}{1-p} + pq(x)\right] - k\left(1-\frac{a}{b}\right)(1-p)\frac{1}{bpx} - \left(\frac{1}{b}-1\right)k^2\frac{1}{bpx^2}$$

Then, because $f''(x) = 0$, the second order derivative of $\Pi_m(x)$ has the same sign as:

$$k\left(1-\frac{a}{b}\right)(1-p)^2\frac{1}{bpx^2} + \left(\frac{1}{b}-1\right)k^2\frac{1}{bpx^3} > 0$$

■

Proof for Lemma 4

Proof. For $p \leq \dot{p}$, let $\underline{p}$ be defined as the solution for p

$$\hat{x}_C = \frac{k}{(1-p) - \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}\frac{p^2}{1-p}} = \bar{x}$$

Note that $\hat{x}_C(p)$ is strictly increasing in p, and $\hat{x}_C(0.5) = 2\frac{k}{1-\theta} < \frac{1+\theta}{\theta}\frac{k}{1-\theta} < \bar{x}$ with $\theta = \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}$. The last inequality above is from Assumption 2'. Therefore, $\underline{p}$ is well defined and unique. Because $\hat{x}_C < \hat{x}_R$, we have $\underline{p} < \bar{p}$, which is the solution to $\hat{x}_R(p) = \bar{x}$.

For $p < \underline{p}$, we have $\bar{x} > \hat{x}_C$, so $\Pi_C(\min\{\hat{x}_C, \bar{x}\}) = \Pi_C(\hat{x}_C)$. Because $p < \underline{p} < \bar{p}$, $\bar{x} > \hat{x}_R$, so $\Pi_R(\min\{\hat{x}_R, \bar{x}\}) = \Pi_R(\hat{x}_R)$. For any p,

$$p^2\hat{x}_C = p^2\frac{k}{(1-p) - \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}\frac{p^2}{1-p}} = p\frac{k}{\frac{1-p}{p} - \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}\frac{p}{1-p}} > p\frac{k}{1 - \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}\frac{p}{1-p}} = p\hat{x}_R$$

and

$$(1-p)\hat{x}_C = (1-p)\frac{k}{(1-p) - \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}\frac{p^2}{1-p}} = \frac{k}{1 - \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}\frac{p^2}{(1-p)^2}} > \frac{k}{1 - \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}\frac{p}{1-p}} = \hat{x}_R$$

Therefore,

$$\Pi_C(\hat{x}_C) = \lambda p^2\hat{x}_C + (1-\lambda)(1-p)^2\hat{x}_C - (1-\lambda)k(1-p) > \lambda p\hat{x}_R + (1-\lambda)\hat{x}_R - (1-\lambda)k(1-p) = \Pi_R(\hat{x}_R)$$

That is, for $p < \underline{p}$, $\Pi_C(\hat{x}_C) > \Pi_R(\hat{x}_R)$.

For $p > \bar{p}$, $\Pi_C(\min\{\hat{x}_C, \bar{x}\}) = \Pi_C(\bar{x}) < \Pi_R(\bar{x}) = \Pi_R(\min\{\hat{x}_R, \bar{x}\})$.

Because functions $\Pi_C(\min\{\hat{x}_C, \bar{x}\})$ and $\Pi_R(\min\{\hat{x}_R, \bar{x}\})$ are continuous in p, there exists

$\tilde{p} \in (\underline{p}, \bar{p})$ such that $\Pi_R(\hat{x}_R) = \Pi_C(\bar{x})$.

$$\begin{aligned}\Pi_R(\hat{x}_R(p)) - \Pi_C(\bar{x}) &= \lambda p[\hat{x}_R(p) - p\bar{x}] + (1-\lambda)(1-p)[\hat{x}_R(p) - (1-p)\bar{x}] \\ &= \frac{[\lambda p + (1-\lambda)(1-p)]k - [\lambda p^2 + (1-\lambda)(1-p)^2]\bar{x}(1-\theta\frac{p}{1-p})}{1-\theta\frac{p}{1-p}}\end{aligned}$$

Define the numerator as a function of p:

$$f(p) \equiv [\lambda p + (1-\lambda)(1-p)]k - [\lambda p^2 + (1-\lambda)(1-p)^2]\bar{x}\left(1-\theta\frac{p}{1-p}\right)$$

Then, we have $f(\tilde{p}) = 0$. The first order derivative is:

$$\begin{aligned}f'(p) = (2\lambda-1)k - 2(p+\lambda-1)\bar{x}\left(1-\theta\frac{p}{1-p}\right) \\ + [\lambda p^2 + (1-\lambda)(1-p)^2]\bar{x}\theta\frac{1}{(1-p)^2}\end{aligned}$$

Because $f(\tilde{p}) = 0$, we have

$$\frac{k}{1-\theta\frac{\tilde{p}}{1-\tilde{p}}} = A(\tilde{p})\bar{x} \Rightarrow k = \left(1-\theta\frac{p}{1-p}\right)A(\tilde{p})\bar{x}$$

where,

$$A(p) \equiv \frac{\lambda p^2 + (1-\lambda)(1-p)^2}{\lambda p + (1-\lambda)(1-p)}$$

Substituting out k in $f'(\tilde{p})$,

$$\frac{f'(\tilde{p})}{\bar{x}} = \left(\lambda\frac{\tilde{p}}{1-\tilde{p}} + (1-\lambda)\frac{1-\tilde{p}}{\tilde{p}}\right)\theta\frac{\tilde{p}}{1-\tilde{p}} - [2p - 1 + (2\lambda-1)(1-A(\tilde{p}))]\left(1-\theta\frac{\tilde{p}}{1-\tilde{p}}\right)$$

Let

$$B \equiv \left(\lambda\frac{\tilde{p}}{1-\tilde{p}} + (1-\lambda)\frac{1-\tilde{p}}{\tilde{p}}\right); \quad C \equiv 2p - 1 + (2\lambda-1)(1-A(\tilde{p})); \quad Z \equiv 1-\theta\frac{\tilde{p}}{1-\tilde{p}}$$

Then $f'(\tilde{p}) > 0$ is equivalent to

$$B(1-Z) - CZ > 0$$

Notice that $B > 0$ and $Z \in [0,1]$ because $\tilde{p} \leq \frac{1}{1+\theta}$ by Assumption 1. Thus, if $C \leq 0$, then $f'(\tilde{p}) > 0$. We are done. Note that

$$\frac{d}{d\lambda}C = -2A(\tilde{p}) - (2\lambda - 1)\frac{dA(\tilde{p})}{d\lambda} = \frac{\tilde{p}(1-\tilde{p})}{(\lambda\tilde{p} + (1-\lambda)(1-\tilde{p}))^2} > 0$$

Then, $C \leq 0$ is equivalent to $\lambda \leq \frac{(1-\tilde{p})^2}{\tilde{p}^2+(1-\tilde{p})^2}$.

When $C > 0$ ($\lambda > \frac{(1-\tilde{p})^2}{\tilde{p}^2+(1-\tilde{p})^2}$), $f'(\tilde{p}) > 0$ is equivalent to $B(1-Z) > CZ \Leftrightarrow Z < B/(B+C)$. Substituting $Z = \frac{k}{A(\tilde{p})\bar{x}}$ (which follows from the $f(\tilde{p}) = 0$ condition), the condition becomes:

$$\frac{\bar{x}}{k} > \frac{B+C}{BA(\tilde{p})} \equiv h$$

That is,

$$h = \left[1 + \frac{(2\tilde{p} - 1 + (2\lambda-1)(1-A(\tilde{p}))\tilde{p}(1-\tilde{p})}{\lambda\tilde{p}^2 + (1-\lambda)(1-\tilde{p})^2}\right]\frac{\lambda\tilde{p} + (1-\lambda)(1-\tilde{p})}{\lambda\tilde{p}^2 + (1-\lambda)(1-\tilde{p})^2}$$

The first order derivative with respect to λ is:

$$\frac{d}{d\lambda}h = \frac{2(1-\tilde{p})\tilde{p}^3[(1-\tilde{p})^2 - (2\tilde{p}-1)\lambda]}{(\lambda\tilde{p}^2 + (1-\lambda)(1-\tilde{p})^2)^3}$$

This has the sign of $(1-\tilde{p})^2 - (2\tilde{p}-1)\lambda]$.

Case 1. $\tilde{p} < 2-\sqrt{2}$. This implies $\frac{(1-\tilde{p})^2}{2\tilde{p}-1} > 1$, so h is strictly increasing in λ. Substituting $\lambda = 1$,

$$h < \frac{2}{\tilde{p}} - 1 < 3$$

Assumption 2' says that:

$$\frac{\bar{x}}{k} > \frac{1+\theta}{\theta(1-\theta)}$$

with $\theta = \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda} \in (0,1)$. The RHS above is minimized at $\theta = \sqrt{2}-1$ and the minimized value is $3 + 2\sqrt{2} > 3$. Therefore Assumption 2' implies:

$$\frac{\bar{x}}{k} > 3 > h$$

Case 2. $\tilde{p} \geq 2-\sqrt{2}$. This implies $\frac{(1-\tilde{p})^2}{2\tilde{p}-1} \leq 1$, so h is maximized at $\lambda = \frac{(1-\tilde{p})^2}{2\tilde{p}-1}$. Substituting $\lambda = \frac{(1-\tilde{p})^2}{2\tilde{p}-1}$, we have

$$h \leq \frac{1-6\tilde{p}+4\tilde{p}^2-\tilde{p}^3}{2-6\tilde{p}+4\tilde{p}^2} \leq \frac{1}{1-\tilde{p}}$$

The second inequality is implies by $\tilde{p} \geq 2-\sqrt{2}$.

Therefore, we have shown $h \leq \frac{1}{1-\tilde{p}} < \frac{\bar{x}}{k}$ by Assumption 2'. Therefore, $f'(\tilde{p}) > 0$ for any solution $\tilde{p}$. Therefore, there cannot be two solutions. If there are two solutions, then there must be a third one where $f'(\tilde{p}) < 0$, which forms a contradiction. ■

Proof for Lemma 5

Proof. At $p = 0.5$, $\Pi_S(\hat{x}_S) = 2\Pi_C(\hat{x}_C) > \Pi_C(\hat{x}_C) = \Pi_C(\min\{\hat{x}_C, \bar{x}\})$.

At $p = 1$, $\Pi_C(\min\{\hat{x}_C, \bar{x}\}) = \Pi_C(\bar{x}) = \lambda\bar{x}$. $\Pi_S(\hat{x}_S) = \lambda k$. That is, at $p = 1$, $\Pi_C(\min\{\hat{x}_C, \bar{x}\}) > \Pi_S(\hat{x}_S)$.

Therefore $\hat{p}_C$ exists.

Note that $\hat{x}_S$ is strictly decreasing in p, so $\Pi_S(\hat{x}_S)$ is strictly decreasing in p.

The function $\Pi_C(x, p)$ is strictly increasing in x. Its partial derivative with respect to p is:

$$2(p+\lambda-1)x + (1-\lambda)k > 0$$

The inequality follows from $p \geq 0.5$ and $\lambda \geq 0.5$. Moreover, $\hat{x}_C$ is strictly increasing in p. Therefore, $\Pi_C(\min\{\hat{x}_C, \bar{x}\})$ is strictly increasing in p. Therefore, $\hat{p}_C$ is unique.

■

Proof for Proposition 2.

Proof. Prove by contradiction. Suppose that type 1 error is not higher. Case 1. When contingent contract is banned, the more profitable choice is a non-contingent safe contract. Type 1 error (innocent conviction) is not higher with the contingent contract implies:

$$(1-p)^2\hat{x}_C - k(1-p) \leq \hat{x}_S - k \Rightarrow \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda} \leq \left(\frac{1-p}{p}\right)^3 + \left(\frac{1-p}{p}\right)^2 - 1$$

If type 1 error (innocent conviction) is not higher with contingent contract, then it must

be that correct conviction is higher for the contingent contract for the contingent contract to be more profitable for the prosecutor:

$$p^2\hat{x}_C > \hat{x}_S \Rightarrow \frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda} > \frac{(1-p)(1-p-p^2)}{p(3p-1-p^2)}$$

Therefore, a necessary condition is that:

$$\left(\frac{1-p}{p}\right)^3 + \left(\frac{1-p}{p}\right)^2 - 1 > \frac{(1-p)(1-p-p^2)}{p(3p-1-p^2)}$$

Define $f(p)$ within this proof.

$$f(p) = \left(\frac{1-p}{p}\right)^3 + \left(\frac{1-p}{p}\right)^2 - 1 - \frac{(1-p)(1-p-p^2)}{p(3p-1-p^2)}$$

This function $f(p)$ is strictly decreasing in p and $f(0.5) = 0$. That is, $f(p) < 0$ for $p > 0.5$. Therefore, we reached a contradiction.

Case 2. When contingent contract is banned, the more profitable choice is a non-contingent risky contract. When $\bar{x}$ is not binding on the contingent contract, type 1 error is higher with the contingent contract than non-contingent risky contract:

$$(1-p)\frac{k}{(1-p)-\frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}\frac{p^2}{1-p}} = \frac{k}{1-\frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}\frac{p^2}{(1-p)^2}} > \frac{k}{1-\frac{1-\beta_0}{\beta_0}\frac{\lambda}{1-\lambda}\frac{p}{1-p}}$$

■

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