Guilty Beyond a Vague and Uncertain Doubt: Burdens of Proof Across Communities

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Abstract

The U.S. Constitution requires proof of guilt in criminal cases "beyond a reasonable doubt." This requirement, however, is never quantified, leaving communities to determine their own definitions. We model the relationship among reasonable doubt, income, and income inequality. How median income affects reasonable doubt depends on the distribution of individuals' disutilty from committing crime. If this disutility has a relatively constant density across income levels, then wealthier societies choose a lower (harsher) reasonable doubt standard. If the density is much higher for poorer societies, however, then wealthier societies choose a higher reasonable doubt standard. Income inequality increases the influence of potential criminals, possibly causing a higher standard. If crime often spills over between wealthier and poorer neighborhoods, however, then income inequality may instead cause a lower standard. Income often does not affect the civil burden of proof, helping to explain the clear quantification of the "preponderance of the evidence" standard.

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1 Introduction

The reasonable doubt standard of proof is a "vital" and "indispensable" component of American criminal jurisprudence.[1] It is the fulcrum point for guilt or innocence; when the prosecution's proof leaves a reasonable doubt in the minds of the jurors about the defendant's guilt, the jurors must acquit the defendant of the alleged crimes.[2] The U.S. Supreme Court has famously held that the reasonable doubt standard of proof is the "prime instrument for reducing the risk of wrongful convictions," and that it provides "concrete substance for the presumption of innocence," which is a "bedrock axiomatic and elementary principle whose enforcement lies at the foundation of the administration of criminal law."[3]

Given its lofty status, one would expect courts to zealously ensure that jurors understand and uniformly apply the reasonable doubt standard. In fact, the opposite is true. The U.S. Supreme Court, and the majority of lower courts, are content to leave the reasonable doubt standard ill-defined and almost never quantified. It is therefore not surprising that overwhelming empirical evidence demonstrates that jurors, lawyers, and judges have widely divergent views about what reasonable doubt actually means.

The absence of guidance on the meaning of reasonable doubt is consistent with another prominent feature of American criminal law: the Sixth Amendment right to be tried in the community where the crime was committed. Differences in economic variables, such as income and income inequality, can affect how a community perceives the risks of either becoming a victim of a crime or of a wrongful conviction. It is therefore plausible that different communities will select different quantitative thresholds of reasonable doubt. This paper models how economic conditions determine these thresholds.

By not imposing a clear and uniform reasonable doubt standard, and by encouraging verdicts that reflect the conscience of the community, the American legal system allows for controversial outcomes. Consider two defendants accused of the same offense. In one community a jury may convict based on its belief that the accused is guilty with probability 0.9, determining that a 10% likelihood of innocence is not reasonable doubt. Another jurisdiction may, however, acquit the defendant having concluded that she is guilty with probability 0.95, determining that a 5% chance of innocence is reasonable doubt. Some might view this scenario as an acceptable result of community standards: others, a grave miscarriage of justice.[4] Our focus is instead to examine how economic disparities may

[1] *In re Winship*, 397 U.S. at 363-64 (1970).

[2] *Id.* at 364.

[3] *Id.* at 363 (internal citation omitted).

[4] Legal arguments on both sides of this debate abound. For example, see Nesson (1979) for an argument in favor of an undefined reasonable doubt standard, and Solan (1999) and Fortunato (1996) for arguments in favor of a more precise

cause such an outcome.

To examine burdens of proof, we develop a three stage model of the legal system. In a given case, jurors lack a non-altruistic motive to correctly judge a defendant's guilt or innocence. Rather than include altruism in jurors' utility functions, however, we assume that the community's values are correlated with the reasonable doubt thresholds employed by juries. This is a standard assumption in the legal literature. Chambers (1998) explains it thusly: "The decision to imprison a citizen is a societal decision. Society has the right and duty to define guilt and the conditions under which defendants will be incarcerated, subject to constitutional limitations. Society seeks to punish the guilty and free the innocent through a justice system that functions to insure that society's goals are met." At bottom, "the question that is ultimately asked in a criminal trial is not merely whether the defendant is guilty, but rather, whether the defendant is certainly guilty. The criminal justice system uses skepticism, in the form of the reasonable doubt standard and the presumption of innocence, to determine whether a defendant is certainly guilty." Necessarily then, "[t]he appropriate level of skepticism to be applied in the criminal justice system depends on the results society wants from the system."[5] Justice Harlan made the same point decades earlier in his concurring opinion in *In re Winship*, where he argued that thresholds of proof represent "the degree of confidence our society [has] in the correctness of factual conclusions," and should "reflect an assessment of the comparative social disutility" of erroneous outcomes.[6]

Our model works as follows: In Stage 1, each agent chooses their own preferred threshold of proof (*i.e.* the level of confidence in guilt needed to convict), knowing that they themselves must live under whichever value the society selects. Each agent must balance her incentive to deter crime through lower thresholds with the desire to minimize the chances of being personally convicted and punished. In Stage 2, a simple median voter mechanism maps from individual preferences to the societal threshold. Finally, in Stage 3, each agent chooses whether or not to commit crime: simple theft in our model. We introduce heterogeneity by assuming that agents obtain disutility from committing crimes. If a trial results, we assume that the petit jury simply implements the community's pre-determined threshold.[7] We assume that for each crime, the criminal justice system identifies a suspect. With positive probability, the suspect is randomly drawn from the population and is actually innocent. Therefore, the lower the reasonable doubt standard, the more likely all members of society are to be wrongfully accused and convicted.

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definition of reasonable doubt.

[5]For a similar argument, see Thomas III and Pollack (1992).

[6]*Winship*, 397 U.S. at 370-371 (Harlan, J. concurring).

[7]In the American criminal legal system, the petit jury typically consists of 6 or 12 people empaneled for the trial of a specific case.

Agents balance their heterogeneous disutility from committing crime, along with the risk of getting caught, against the benefits of successfully stealing wealth when deciding whether to commit a crime. Lower reasonable doubt thresholds increase the risk of being convicted and punished, and thus deter crime. This deterrent effect is stronger when the density of agents' disutility from crime is higher. The relationship between median income and the quantitative meaning of reasonable depends on this density. When we assume that the disutility from committing a crime is uniformly distributed, then it constant across income levels, and we show that wealthier societies choose a lower (harsher) reasonable doubt standard. This is because richer societies have lower crime rates and therefore are able to worry less about wrongful accusations, which may then become wrongful convictions.

When we instead assume that agents' disutility from crime is normally distributed, there are a pair of potential results. If the model is parameterized to yield low reasonable doubt standards, then the reasonable doubt threshold is a U-shaped function of income where some intermediate income level yields the lowest possible threshold. If the model is parameterized to yield high reasonable thresholds, however, then the reasonable doubt threshold is always increasing in income. This may occur because as a society becomes wealthier, crime rates fall, which moves the model further down the left tail of the normal distribution. Here, the deterrent effect is weaker and agents thus prefer a higher threshold in order to reduce the risk of being wrongfully convicted.

We next consider the effect of income heterogeneity and find competing effects. Our model is set up so that a majority of individuals will never choose to be criminals. When income is homogeneous, potential criminals are a minority and are unable to affect the reasonable doubt standard. Income heterogeneity, however, gives them some influence in the electoral process. If theft does not cross income levels (*e.g.* the rich only steal from the rich and the poor only steal from the poor), then society chooses a higher reasonable doubt threshold. If we allow crime to cross over among income groups, however, then this effect may be reversed. In this case, if agents' disutility from committing crime is normally distributed, then poorer agents are more effectively deterred from crime then wealthier agents. If the median voter is at risk of crime from poorer criminals, they may then respond by selecting a lower reasonable doubt threshold, making convictions easier to obtain.

Finally, we extend the model to consider civil burdens of proof. In contrast to the reasonable doubt standard, the civil burden of proof - preponderance of the evidence - is both lower than reasonable doubt and definitively quantified (as greater than 50%), both in the law and as part of the instructions given to jurors before they begin deliberations. There is ample evidence that the legal system does not weigh wrongful liable verdicts more heavily than wrongful not liable verdicts. We show that this causes all societies, regardless of income, to prefer the lowest possible burden of proof. We interpret the preponderance of the evidence standard as a corner solution, and argue that the clarity of the

standard arises from the lack of a need to allow different societies to choose their own standard.

Our paper is organized as follows. Section 2 summarizes the legal landscape, including the confusing and often contradictory efforts of courts to explain reasonable doubt. Section 3 describes the related economics literature. Section 4 develops the model, and Section 5 presents our formal propositions which are proven beyond a reasonable doubt in a separate appendix. Section 6 concludes.

2 Legal Landscape

We examine the intersection of two constitutional rights: the right of the accused to protection from "conviction except upon proof beyond a reasonable doubt of every fact necessary to constitute the crime charged"[8] and the right to trial "by an impartial jury of the State and district wherein the crimes shall have been committed."[9] These two rights interject abstruseness into the system, which enables communities to select their own reasonable doubt thresholds.

We start with the reasonable doubt standard of proof. In every criminal trial, jurors are instructed that they must acquit unless the prosecution has proved the defendant's guilt beyond a reasonable doubt. Reasonable doubt is almost never quantified;[10] and there is no legal consensus on what that number would be.[11] Instead of quantifying the term, reasonable doubt is either defined qualitatively or it is not defined at all.

This ambiguity persists because the U.S. Supreme Court has never quantified reasonable doubt. The Court has, however, repeatedly instructed that "[a] 'reasonable doubt,' at a minimum, is one based upon reason."[12] This is intended to be instructive, and not sarcastic. The best one can say is that the

[8] *In re Winship*, 397 U.S. 358, 364 (1970).

[9] U.S. Constitution, Amendment VI.

[10] Kramer and Koenig (1990) collect jury instructions that have attempted to quantify reasonable doubt; all were subsequently struck down. In other cases, football analogies have been used to quantify reasonable doubt. In *Brooks v. State*, 323 S.W.3d 893, 923 (Tex. Crim. App. 2010), the appellate court analogized the reasonable doubt standard to a football field, where one end zone represented "no evidence" and other "conclusive evidence;" the court explained, "reaching midfield is never enough to meet the beyond a reasonable doubt standard." In *State v. Casey*, 2004 WL 405738, *6-7 (Ohio App. 2 Dist. 2004), the prosecutor told the jurors during closing arguments: "I like to make it kind of like a football field where you start at one end and you go to the other. If you go all the way and make a touchdown, that's like a hundred percent. That's beyond no doubt. I like to say reasonable doubt is kind of like 75 percent. Somewhere - 75 and 90. Now, you're not going to hold me to going all the way for a touchdown, are you?" The appellate court refused to overturn the defendant's conviction because of that analogy.

[11] McCauliff (1982) surveys 171 federal judges to quantify the conviction threshold for reasonable doubt. The judges gave varying responses: 126 judges said 90% or more (56 judges said 90%, 3 judges said between 92-94%, 31 judges said 95%, 1 judge said 97%, 6 judges said 98%, 8 judges said 99%, and 21 judges said 100%); 8 judges said 75% and 3 judges accepted even lower thresholds (1 judge said 50%).

[12] *Victor v. Nebraska*, 511 U.S. 1, 17 (1994); *Jackson v. Virginia*, 443 U.S. 307, 317 (1979); *Johnson v. Louisiana*, 406

Court's jurisprudence has been confusing. For example, the Court has whipsawed between defining reasonable doubt as the degree of certainty "you would be willing to act upon in the more weighty and important matters relating to your own affairs,"[13] only to later hold that reasonable doubt should be worded "in terms of the kind of doubt that would make a person hesitate to act, rather than the kind on which [a person] would be willing to act."[14] The Court has also considered a variety of different instructions that define reasonable doubt using a combination of different phrases. The Court has unanimously held that "grave uncertainty," plus "actual substantial doubt," and "moral certainty," is unconstitutional.[15] It has also unanimously held that "moral evidence," plus "not a mere possibility of doubt," and "moral certainty," passes constitutional muster.[16] The Court divided on the question of whether "strong possibilities," plus "substantial doubt," and "moral certainty," offend the constitution; ultimately, the majority concluded that it does not.[17] Obviously, these fine-tuned distinctions are lost on the average juror. By the Court's own admission, its "attempts to explain the term reasonable doubt do not usually result in making it any clearer to the minds of the jury."[18] And, for all the Court's trouble, it appears that the lower courts are not listening. For example, ten of twelve Circuit Courts of Appeal have reviewed and upheld instructions using the phrase "moral certainty" despite the U.S. Supreme Court's reluctance to condone the definition.[19]

Because the U.S. Supreme Court has failed to provide clear guidance on the proper legal meaning of reasonable doubt, and because an improper jury instruction may be grounds for the reversal of a criminal conviction,[20] many lower courts prohibit defining the term at all.[21] In these cases, jurors are informed that the government must prove its case "beyond a reasonable doubt," and nothing more.[22]

Empirical evidence confirms that jurors are ill-informed about what reasonable doubt means or how to apply the concept, regardless of whether they have received a qualitative instruction. The legal system does clearly interpret reasonable doubt as a higher burden than preponderance of the evidence,

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U.S. 356, 360 (1972).

[13] *Hopt v. People*, 120 U.S. 430, 440 (1887).

[14] *Holland v. United States*, 348 U.S. 121, 138 (1955).

[15] *Cage v. Louisiana*, 498 U.S. 39, 41 (1990) (per curiam).

[16] *Victor*, 511 U.S. at 10-17 (the Sandoval instruction).

[17] *Id.* at 18-23 (the Victor instruction).

[18] *Miles v. United States*, 103 U.S. 304, 312 (1880).

[19] See Corwin (2001).

[20] See *Sullivan v. Louisiana*, 508 U.S. 275, 281-82 (1993).

[21] *Victor*, 511 U.S. at 5 ("the Constitution neither prohibits trial courts from defining reasonable doubt nor requires them to do so as a matter of course.")

[22] *Id.* at 5, "[S]o long as the court instructs the jury on the necessity that the defendant's guilt be proved beyond a reasonable doubt, the Constitution does not require that any particular form of words be used in advising the jury of the government's burden of proof."(internal citation omitted). For a discussion of the varying approaches to defining, or not defining, reasonable doubt, see Diamond (1990).

which is understood as greater than 50%. Strawn and Buchanan (1976), however, find that 23% of instructed jurors, *i.e.* jurors that had received some instruction on the meaning of reasonable doubt, believed that when the weight of circumstantial evidence was equally balanced between guilt and innocence, the defendant should be convicted. Saxton (1998), finds similar results; 27% of instructed jurors either did not know or incorrectly believed that a greater than a 50% chance of guilt was sufficient to convict, and an additional 15% were only "pretty sure" that a greater degree of confidence was required. Kramer and Koenig (1990) find that only 25% of instructed jurors correctly understood that reasonable doubt does not mean "any possibility, no matter how slight," and only 31% of instructed jurors correctly understood that 100% certainty was not required in order to convict.[23]

Jury verdicts in criminal cases reflect a community's idiosyncratic view of the quantum of proof necessary for a conviction, rather than some uniformly-applied benchmark.[24] This is consistent with the Sixth Amendment's guarantee of a trial "by impartial jury of the State and district wherein the crime shall have been committed," which we turn to next.

The "insistence upon community participation in the determination of guilt or innocence" is a fundamental component of criminal trials.[25] A community-based jury gives the defendant an "inestimable safeguard against the corrupt or overzealous prosecutor and against the compliant, biased or eccentric judge."[26] Jury verdicts are intended to reflect "the commonsense judgment of a group of laymen" and "the shared [community] responsibility that results from that group's determination of guilt or innocence."[27]

One of the reasons why the jury must be "truly representative of the community,"[28] is because juries are expected to "express the conscience of the community."[29] The law recognizes that juries "inevitably make decisions based on community values."[30] For example, in *Witherspoon v. Illinois*, the U.S. Supreme Court recognized that "a jury that must choose between life imprisonment and capital punishment can do little more - and must do nothing less - than express the conscience of the

[23] Additional empirical research in this area, which is largely consistent with the above-referenced studies, is summarized in Solan (1999).

[24] In some cases, jurors are told that the reasonable-doubt standard is more exacting than the preponderance of the evidence standard, which is routinely quantified as more than 50%.

[25] *Duncan v. Louisiana*, 391 U.S. 145, 156 (1968).

[26] *Id*. at 156.

[27] *Williams v. Florida*, 399 U.S. 78, 100 (1970); see also 4 W. Blackstone, Commentaries on the Laws of England 343 (1769) (Blackstone described "trial by jury" as requiring that "the truth of every accusation should afterwards be confirmed by the unanimous suffrage of twelve of [the defendant's] equals and neighbors.")

[28] *Taylor v. Louisiana*, 419 U.S. 522, 527 (1975); *Glasser v. United States*, 315 U.S. 60, 85-86 (1942); *Smith v. Texas*, 311 U.S. 128, 130 (1940).

[29] *Witherspoon v. Illinois*, 391 U.S. 510, 519 (1968).

[30] *Spaziano v. Florida*, 468 U.S. 447, 486-87 (1968) (Stevens, J., concurring in part and dissenting in part).

community on the ultimate question of death."[31] The Court added that "one of the most important functions any jury can perform...is to maintain a link between contemporary community values and the penal system - a link without which the determination of punishment would hardly reflect the evolving standards of decency that mark the progress of a maturing society."[32] In sum, a jury verdict in a criminal case is intended to embody "community values" and society's definition of "reasonable doubt."

3 Related Literature

A small literature in economics examines the causes and effects of burden of proof thresholds in a legal system. This literature typically assumes that juries are not directly affected by their verdicts but instead are motivated by altruism; they obtain utility from ruling correctly and disutility from either wrongful convictions of the innocent or wrongful acquittals of the guilty. Andreoni (1991), for example, develops a model where jurors require a higher threshold of proof for harsher punishments. It thus follows that unduly harsh punishments may result in less deterrence and more crime.[33] Lando (2009) examines reasonable doubt standards in a model that he then applies to violent crimes against women. As in our model, agents make a Becker (1968) type choice of whether to commit a crime for a given reasonable doubt threshold. That paper focuses on solving for the optimal reasonable doubt standard for a given social welfare function as opposed to solving for a reasonable doubt standard as an endogenous result of agents' preferences. Mungan (2011), like us, assumes that reasonable doubt thresholds are a function of the entire criminal justice system and not just individual jurors acting altruistically. That paper shows that, if non-criminals devote resources to reducing their risk of wrongful convictions, then wrongful convictions may be worse than wrongful acquittals and it is thus optimal to have a high threshold of proof. Our focus, however, is on the relationship among economic conditions and reasonable doubt standards, explaining the American legal system's reluctance to clearly articulate (or quantify) and standardize reasonable doubt thresholds, and understanding why different communities may have different thresholds.

Other papers examine thresholds of proof in less related ways. Curry and Klumpp (2009) model how a jury decides whether evidence reaches the level of a given reasonable doubt threshold. They find that differences in income among racial groups may affect a jury's prior beliefs, which causes the amount of evidence needed to convict to vary across the race of the accused. This result may

[31] *Witherspoon*, 391 U.S. at 519.

[32] *Id*. at 520 n. 15 (internal citation omitted); *Spaziano v. Florida*, 468 U.S. 447, 462 (1984).

[33] Feess and Wohlschlegal (2009) obtain a similar result and show that excessive punishments may also reduce the informativeness of evidence.

then reinforce the existing prior beliefs about different groups' guilt. Other papers examine how the threshold of proof affects the level of effort supplied by either prosecutors or defendants.[34] Kaplow (2011) examines the effect of reducing the threshold of proof and the resulting deterrence of benign behavior. Demougin and Fluet (2006 and 2008) examine the optimality of the preponderance of the evidence standard. Rizzolli and Saraceno (2013), and Kaplow (1994) show that if punishment is costly, then wrongful convictions are more harmful than wrongful acquittals, possibly justifying higher burdens of proof.

Our paper is also related to a literature that examines the relationship among aggregate crime rates and economic conditions. Benoit and Osborne (1995) examine the optimal levels of enforcement and redistributive transfers in a model where these policies can both deter crime and result in wrongful convictions. The probability of wrongful convictions does not depend on an endogenous reasonable doubt threshold. Chiu and and Madden (1998) find that income inequality increases burglary rates. Di Tella and Dubra (2008) find that belief in the "American Dream" results in harsher punishments.

Finally, our paper is related to the long literature that examines the relationship between crime and the expected punishment. In the seminal paper of Becker (1968), as well as many related papers, harsher punishments provide a greater deterrent effect.[35] Often, the optimal policy is an extreme punishment, possibly implemented with low probability. In our model, it is also the case that as the punishment approaches infinity, crime rates fall to zero. Our approach, however, is to rule out such scenarios (*e.g.* imposing the Eighth Amendment's prohibition on cruel and unusual punishment) and instead examine how societies quantify reasonable doubt when having to balance the desire to deter crime with the risk of being wrongfully convicted.

4 Model

We develop a three stage model that determines a society's reasonable doubt threshold. In the first stage, each agent chooses a preferred reasonable doubt threshold. In stage two, a simple median voter mechanism maps from individuals' reasonable doubt thresholds to a society-wide threshold. Finally, in stage three, each agent decides whether or not to commit crime.

We assume the following utility function:

$$U(y, d, p, j) = r(y + p - C(y)) - jp - p\Omega f(d) - \tau\Omega q(d)C(y) \tag{1}$$

where $r(y + p - C(y))$ is a function equating net income to utility, $y \in (1, \infty)$ is gross income, and

[34] See, for example, Rubinfeld and Sappington (1987), Miceli (1990), and Yilankaya (2002).

[35] Other prominent examples include Erlich (1973) and Furlong (1987).

p equals one if the agent chooses to steal one unit and zero otherwise.[36] We denote $r^{'}(y)$ as the utility gain from stealing one-unit. We assume:

(A1): $\frac{\partial r^{'}(y)}{\partial y} < 0$, $\frac{\partial^2 r^{'}(y)}{\partial y^2} > 0$, and as $y \to \infty$, $r^{'}(y) \to 0$.

For now, we assume that criminals only steal from people with the same income. We relax this assumption in Section 5.2.

(A2): Criminals only steal from other agents with the same y and theft is evenly distributed within each income type. The loss from crime is then $r^{'}(y)C(y)$.

Our assumption that agents only steal from people with the same income causes the loss from theft to be proportional to the crime rate for a given y. (A2) also assumes that the loss from theft is proportional to a criminal's utility gain from commuting theft, $r^{'}(y)$. This may be seen as a linear approximation to agents' utility functions which simplifies the analysis that follows.

The parameter j is agent's intrinsic disutilty from committing crime. Heterogeneous values allow the model to generate crime rates less than one but greater than zero. We denote $C(\bar{j}, \sigma_j^2)$ as the distribution of j and assume that it is continuous within its support and is twice-differential. We further assume that $\bar{j}$, the mean of j, is greater than or equal to one. This will later rule out pathological cases where the crime rate is greater than 50%. Later, we focus on cases where $C(\bar{j}, \sigma_j^2)$ is either a normal or uniform distribution.

If an agent is convicted of a crime, she is punished and obtains disutility equal to $\Omega > 1$. The function $f(d)$ is the probability that a criminal is correctly convicted and punished. The function $q(d)$ is the probability that a crime results in a wrongful conviction. Wrongful convictions yield disutility equal to $\tau\Omega$, where $\tau \geq 1$ is the weight on wrongful convictions relative to just ones. We assume that j is unobservable and the likelihoods of being convicted (justly or wrongfully) may not depend on its value.

When a crime occurs, the criminal justice system exogenously identifies a suspect.[37] With probability $g \in [0, 1]$ the guilty party is correctly identified and with probability $1 - g$, an innocent person is randomly chosen as the suspect. The distribution of g, $m(\bar{g}, \sigma_2^g)$, is assumed to be continuous and twice-differentiable, although none of our results are sensitive to its exact nature. Potential criminals know the distribution of g, but not its realized value, when deciding whether to commit a crime. A conviction occurs if and only if $g > d$, where d is the reasonable doubt threshold.

[36] Restricting $y \geq 1$ ensures that agents do not have negative net incomes but does not otherwise affect our results.

[37] There may also be some probability that the criminal justice fails to identify any suspect. This addition, however, is isomorphic to assuming a lower value of Ω, and does not affect any of our results. We thus omit it from the model.

The probability of a correct conviction for a given crime is thus:

$$f(d) = \int_d^1 g\ m(g)dg \tag{2}$$

The probability being wrongfully accused and convicted for each crime is thus:

$$q(d) = \int_d^1 (1-g)\ m(g)dg \tag{3}$$

The function $q(d)$ is the probability of being both wrongfully accused and wrongfully convicted. We assume that being wrongfully accused but not convicted, equal to $\int_0^d (1-g)\ m(g)dg$, does not cause disutility. We considered an alternate version where wrongful accusations without convictions also yield disutility. This reduces the marginal disutility of being convicted which causes agents to worry less about wrongful convictions, and thus choose a lower reasonable doubt threshold. It is thus nearly identical to choosing a lower value of τ.

We begin by examining communities with homogeneous income levels, focusing on how this level of income affects crime and the reasonable doubt threshold. We thus make the following assumption:

(A3): If a wrongful conviction occurs, then a random agent with the same y as the true culprit is punished.

We discuss the implications of relaxing this assumption in Section 5.2. It follows from (A3) that the expected utility loss from wrongful convictions is proportional to the product of the crime rate, $C(y)$, and the probability of each crime resulting in a wrongful conviction, $q(d)$.

We now discuss each of the model's three stages in reverse order.

Stage 3, Choosing Crime

The final stage of the game is a Becker (1968) type binary choice of whether to commit crime. Agents choose $p(y,j)$ taking d, and thus $f(d)$, $q(y)$, and $C(y)$ as given. An agent of type (y,j) commits a crime if and only if the marginal benefit outweighs the marginal increase in the risk of punishment plus the intrinsic disutility of stealing:[38]

$$\begin{cases} \text{if } r^{'}(y) \geq j + \Omega f(d) & \text{then } p = 1 \\ \text{if } r^{'}(y)) < j + \Omega f(d) & \text{then } p = 0 \end{cases} \tag{4}$$

The crime rate is then just the cumulative distribution function of j at $r^{'}(y) - \Omega f(d)$:

[38] We do not, however, rule out negative values of j where agents obtain utility from crime.

$$C(r^{'}(y)) - \Omega f(d)) \tag{5}$$

The crime rate, hereafter $C(\cdot)$, displays two intuitive properties. First, the crime rate is decreasing in income. Poorer agents possess a higher marginal utility of income than wealthier agents and thus benefit more from theft. Second, the crime rate is increasing in the reasonable doubt threshold. As d increases, a criminal is less likely to be convicted, and the deterrent effect of punishment is diminished.

Stage 2: Societal Choice of Reasonable Doubt

We assume that the societal-wide reasonable doubt threshold, $d(y)$, is simply the median individual standard in a given population of agents. Our focus is on society's determination of reasonable doubt, not the dynamics of juries. We thus assume that each defendant's probability of guilt, g, is perfectly observable to all members of a potential jury, and that juries simply implement society's standard. It thus follows that the defendant is convicted, or agrees to a plea bargain, if and only if $g > d$.[39]

Our model assumes that the controlling legal authority does not impose a common reasonable doubt standard, but that local communities do, and that they are able to implement it. We view the choices of judges and prosecutors, and public funding decisions as mechanisms that allow for such implementation. An alternate approach, however, is to instead assume that the reasonable doubt standard reflects the preferences of individual juries, most plausibly by assuming that the actual threshold matches that of the juror with the highest threshold.[40] For the analysis of homogeneous societies that follows, this approach makes no difference because all agents choose the same standard. For the analysis of heterogeneous societies, however, this alternate approach raises the threshold to match that of the juror with the highest doubt threshold. This would thus cause heterogeneous societies to set higher reasonable doubt thresholds, making convictions harder to obtain, and causing a higher crime rate.

Stage 1: Individual Choice of Reasonable Doubt

We now solve for individuals' preferred reasonable doubt standard, $d(y, j)$. Our assumption that $\bar{j} \geq 1$ ensures that the median agent in a homogeneous (in income) society always chooses $d(y, j)$

[39]It is estimated that 94% of state convictions and 97% of federal convictions result from plea bargains. (See *Missouri v. Frye*, 132 S.Ct. 1399, 1407 (2012)) Because both g and d are known at the trial stage in our model, a plea bargain will occur if the prosecutor and defendant are able to bargain over even a small surplus. This surplus may include the cost and effort involved with holding a trial.

[40]In most cases, guilty verdicts require unanimity.

knowing that she will not commit a crime. We thus only consider this type of agent's choice of a reasonable doubt threshold when analyzing homogeneous societies in Section 5.1. Agents choose $d(y, j)$ knowing that higher values result in more crime and thus more property loss. Agents must also consider the effect of d on their probability of being wrongfully accused and convicted. Higher values of d reduce the risk of wrongful conviction.

Differentiating (1) with respect to d yields the associated first-order condition:

$$-r^{'}(y)C_d(\cdot) - \tau\Omega C(\cdot)q_d(d) - \tau\Omega C_d(\cdot)q(d) = 0 \tag{6}$$

Consider each of the three terms in (6). The first term is negative and represents how a higher d increases crime rates and thus the loss from property theft. The second term is positive and represents how a higher d reduces the probability that a wrongful accusation becomes a wrongful conviction. The final term is negative and represents that, by raising crime rates, a higher d increases the risk of being wrongfully accused. Because the sum of the second and third terms in (6) is positive, it follows that higher values of d reduce the risk of wrongful convictions. For the functional forms from (3) and (5), this first-order condition may be re-written as:

$$-\frac{dr^{'}(y)c(\cdot)}{\tau} + (1-d)C(\cdot) - d\Omega c(\cdot)\int_d^1 (1-g)m(g)dg = 0 \tag{7}$$

where $c(\cdot)$ is the probability density function of j. The resulting solution is the optimal choice of reasonable doubt for an agent of income y and sufficiently low j that they will not commit a crime even if $f(d) = 0$.

5 Results

5.1 Homogeneous Society Results

We begin by comparing results for different societies, each of which is homogeneous in income and is free to choose their own reasonable doubt standard. Without income heterogenity, the societal reasonable doubt standard is simply $d(y, j)$ for any j that is sufficiently high to rule out criminality.

We start by analyzing how the weight placed on wrongful convictions, τ, affects the reasonable doubt threshold and crime rates.

Proposition 1. *$d(y)$ and $C(y)$ are both increasing in τ, and as $\tau \to \infty$, $d(y) \to 1$*

Proof: See Proof Appendix.

Increasing the reasonable doubt threshold has two effects on the risk of wrongful convictions. First, for each wrongful accusation, a higher threshold reduces the risk that the accusation turns into a wrongful conviction. Second, a higher threshold increases the crime rate and hence the amount of wrongful accusations. Proposition 1 shows that the former effect dominates and as society cares more about wrongful convictions, they raise the doubt threshold to make convictions harder to obtain. This then results in a higher crime rate.

We next examine the impact of income on the reasonable doubt standard. These results, however, depend on the distribution of j. We start with the case where j is uniformly distributed:

Results where j is uniformly distributed

We denote $(\bar{j} - \frac{\delta}{2}, \bar{j} + \frac{\delta}{2})$ as the interval on which j is distributed. Equation (7) may be then be re-written as:

$$-\frac{dr^{'}(y)}{\tau} + (1-d)\left(r^{'}(y) - \Omega f(d) - (\bar{j} - \frac{\delta}{2})\right) - d\Omega q(d) = 0 \tag{8}$$

We now consider a special parameterization where $\tau = 1$, which implies that agents do not differentiate between being justly and wrongfully punished. This scenario causes agents to prefer especially low levels of d.

Proposition 2. $d(y) < \frac{1}{1+\tau^{-1}}$. *Thus if* $\tau = 1$, *then* $d(y) < \frac{1}{2}$.

Proof: See Proof Appendix.

Blackstone's famous formulation states that "better that ten guilty persons escape than that one innocent suffer."[41] More generally, the sentiment that wrongful convictions are worse then wrongful acquittals motivates values of τ greater than one. Proposition 2 considers a special case that rejects this sentiment. The resulting burden of proof is implausibly low when compared to the American (and most other) legal systems. Beyond a reasonable doubt is widely understood to be a higher burden than preponderance of the evidence, which the legal profession views as a greater than 50% standard.[42] Proposition 2 shows that treating errors asymmetrically is necessary for yielding empirically plausible reasonable doubt thresholds.[43]

We now turn to the central question of how income affects the reasonable doubt standard.

Proposition 3. *If j is uniformly distributed, then both $d(y)$ and $C(y)$ are decreasing in y.*

[41] See Blacktone, W. 1765. *Commentaries on the Laws of England*. Oxford, Clarendon Press.

[42] *Turpin v. Merrell Dow Pharmaceuticals, Inc.*, 959 F.2d 1349, 1357 n. 2 (6th Cir. 1992) (preponderance of the evidence means more than 50%).

[43] Simon (1970) conducts an experiment on undergraduate sociology majors and estimates d at around 75%.

Proof: See Proof Appendix.

As income increases, there are two effects. The first is that a lower marginal utility of income reduces the impact of crime, which incentivizes higher values of d. The second is that the crime rate decreases which reduces the risk of wrongful accusations and thus wrongful convictions. This incentivizes agents towards a lower d. Proposition 3 shows that the latter effect dominates the former, and wealthier societies choose a lower reasonable doubt threshold. Lower thresholds of proof and higher income then combine to reduce the equilibrium crime rate.

Consider an example of two identical crimes where the identified suspect is guilty with probability 85%. Proposition 3 suggests that, despite the identical nature of the allegations, the accused may be convicted in a wealthy society but acquitted (or never prosecuted) in a poorer society. Although the U.S. Supreme Court has never explicitly weighed in the the constitutionality of this disparate treatment, existing caselaw allows it by default. It is also worth noting that it is consistent with standard notions of economic efficiency in our model.

The probability density function for j, $c(\cdot)$, represents the deterrent effect of lowering d. A useful feature of the uniform distribution is that the deterrent effect is invariant to changes in y. When we instead assume a normal distribution, increasing y will weaken the deterrent effect, which will allow for outcomes different than Proposition 3.

We next consider the effects of harsher punishments in the model.

Proposition 4. *If j is uniformly distributed, then as Ω increases, both $d(y)$ and $C(y)$ decrease.*

Proof: See Proof Appendix.

Proposition 4 contrasts with the major result of Andreoni (1991). In his model, as punishments increase, jurors employ a higher threshold of proof in order to avoid the increasing disutility from a wrongful conviction. In our model, however, harsher punishments endoenously reduce the crime rate which reduces the risk of wrongful accusations. Proposition 4 shows that this effect is strong enough so that agents prefer a lower reasonable doubt threshold. It then follows that a lower d and a harsher punishment combine to yield a lower crime rate.

Much of the economics of crime literature focuses on the optimal choice of punishment. Often, as in Becker (1968), the optimal policy is to choose the maximum punishment in order to achieve maximum deterrence. If we allow agents to choose Ω, then our model delivers a similar result where severe punishments can deter all crime.[44] Cruel, unusual, and excessive punishments are disallowed,

[44] An earlier version of the paper included a fraction of agents who always commit crimes. Including these serial criminals makes it impossible to deter all criminals and wrongful convictions always remain a possibility. Large punishments will thus not generally be optimal.

however, in most modern legal systems.[45] Our approach is therefore to consider the choice of d where voters are constrained by the maximum possible punishment they can impose for a given crime.

Results where j is normally distributed

We now consider the case where j, agents' disutility from committing a crime is normally distributed. Normality causes the deterrent effect of changing d, $c(\cdot)$ to no longer be constant. Because we limit our attention to the left half of the distribution, where crime rates are less than one-half, the deterrent effect is stronger for higher crime rates. The causes the model under normality to behave similarly to the case where j is uniformly distributed for higher crime rates. For lower crime rates, however, the model's behavior is very different.

Proposition 5. *If j is normally distributed, then for sufficiently low crime rates, $d(y)$ is increasing in y.*

Proof: See Proof Appendix.

This result is in contrast with those of the uniform distribution where higher income always leads to a lower reasonable doubt threshold. The proof relies on the first derivative of $c(\cdot)$, which is zero for a uniform distribution but positive for a normal distribution where $C(y) < \frac{1}{2}$. As income increases, crime rates fall, and the deterrent effect of lowering d weakens. For low enough crime rates, this effect dominates and wealthier societies choose higher values of d. We note that we cannot rule out cases where as y increases, d rises by so much that the crime rate increases.

Proposition 6. *If j is normally distributed, and if $d(1)$, is sufficiently low, then $d(y)$ is a U-shaped function of y so that an intermediate value of y minimizes $d(y)$.*

Proof: See Proof Appendix.

Propositions 5 and 6 combine to yield an uncertain overall relationship between y and $d(y)$. The conditions for either Proposition 5 or 6, but not both, are valid at $y = 1$ and this determines which of two distinct cases arises.

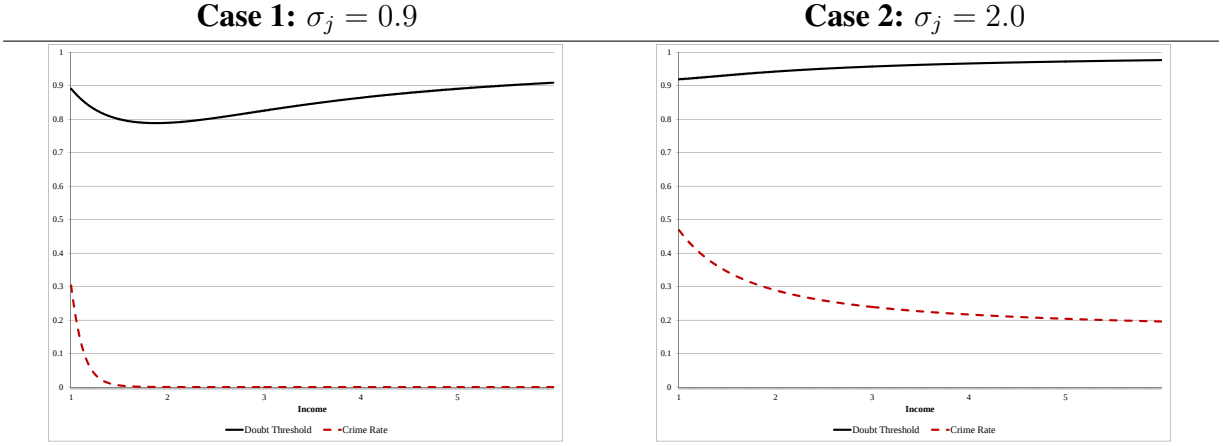
Case 1: Low Doubt Calibration. In this case $d(1)$, the reasonable doubt standard for the minimum level of income, is low enough so that Proposition 6 applies. As income rises, $d(y)$ initially falls. For high enough levels of income, however, this relationship reverses and $d(y)$ begins to increase.

[45] In the United States, for example, the death penalty is only allowed for aggravated murder and is not a feasible punishment on our model of property theft.

Case 2: High Doubt Calibration. Here, $d(1)$ is too high for 6 to apply. $d(y)$ is thus universally an increasing function of y.

We now provide a numerical example. Many parameters affect which case arises, but we focus on σ_j, the standard deviation of agents' dislike for being criminals. Lower values make the deterrent effect stronger and induce agents to prefer a lower value of d. We set $\tau = 10$, its exact value from Blackstone's formulation, and set $\Omega = \bar{j} = 1$. We assume $r'(y) = \frac{1}{y}$, approximating logarithmic utility. Finally, we assume that g is uniformly distributed between zero and one. In this example, setting $\sigma_j = 0.9$ yields a low enough value of $d(1)$ for Case 1 to apply. When we raise σ_j to 2.0, however, the deterrent effect is weaker and agents thus choose a higher value of $d(y)$. Now $d(1)$ is higher so that Case 2 applies and $d(y)$ always increases along with y. Figure 1 illustrates each case along with the resulting crime rate.

Figure 1: Relationship Between Reasonable Doubt, Income, and the Crime Rate



So far, we have focused on how different income levels affect the reasonable doubt standard, holding all other parameters constant. It is plausible, however, that some of the model's other parameters might also be affected by income. One example is g, the probability that the identified suspect is guilty. We might expect that a wealthier society will have a better funded criminal justice system that yields higher value of g than a poorer society. We can model the effect of a superior criminal justice system by switching to an alternate distribution of g that first-order stochastically dominates the original. Doing so, for a given d, results in a higher rate of correct convictions ($f(d)$ increases). The effect on $q(d)$, and hence $d(y)$, however, is ambiguous. We can identify cases where a better criminal justice system leads to either a higher or lower reasonable doubt threshold.

Propositions 2 and 4 do not cleanly extend to the case where j is normally distributed. It is straightforward to show, however, that a sufficient condition for $\tau = 1$ yielding $d(y) < \frac{1}{2}$ is that

$\frac{r'(y)c(\cdot)}{C(\cdot)} \leq 1$. This will be true if σ_j or y are sufficiently large. We also show that if Ω is sufficiently large, then further increases will result in a higher $d(y)$. We also can show that for high enough crime rates, $\frac{\partial d(y)}{\partial \Omega} < 0$, but for low enough crime rates, $\frac{\partial d(y)}{\partial \Omega} > 0$.

5.2 Heterogeneous Society Results

We now allow for income heterogeneity in the model. We denote $\bar{y}$ as the income level for some homogeneous society and compare that to a heterogeneous society where income is symmetrically distributed around $\bar{y}$. The median voter continues to choose the societal reasonable doubt standard. One change is that potential criminals may now impact the threshold whereas they have no ability to do so in the homogeneous society. Because higher values of d reduce criminals' chances of being justly convicted, this causes a higher reasonable doubt standard. For now, we continue to maintain (A2), the assumption that criminals only steal from agents with the same income level.

Proposition 7. *In a heterogeneous society where income is symmetrically distributed around $\bar{y}$, the societal reasonable doubt standard is higher than for a homogeneous society with income equal to $\bar{y}$. The heterogeneous society also displays a higher crime rate.*

Proof: See Proof Appendix.

When income is homogeneous, j is the model's only source of heterogeneity. Our assumption that $\bar{j} \geq 1$ ensures that the majority of agents are non-criminals for all income levels and they all choose the same doubt standard, which is then the societal standard. Criminals' preferences have no impact. When y is heterogeneous, however, individuals' preferred doubt standard becomes a continuous distribution. Consider a hypothetical distribution where all agents choose $d(y, j)$ as if they are would never commit a crime. Now suppose that potential criminals optimize. There will some potential criminals (*e.g.* those with high values of both j and y) whose $d(y, j)$ is above the median when they ignore their potential criminality, but for whom it is below the median when they consider it. This then lowers the median value of $d(y, j)$.

There are two reasons why heterogeneity results in a higher crime rate. The first is the direct effect of a higher reasonable doubt standard. The second, as shown in the proof to Proposition 7, is that $C(y)$ is a convex function of the crime rate so that lowering income raises crime faster than raising y reduces crime. The empirical literature is divided on whether inequality increases crime. Fajnzylber *et. al.* (2002) find a positive correlation between income inequality and murders and robberies, and Freeman (1996) presents evidence that inequality increases crime. Kelly (2000), however, finds a similar result for violent crimes, but not property crimes.

Crime Spillovers

We now drop our assumption that criminals only steal from agents with the same income. We replace (A2) with:

(A4): The costs of theft are felt equally throughout a society and all individuals, regardless of income, are equally likely to be wrongfully accused.

This change has no effect when analyzing a society with homogeneous income. We thus continue to focus on the model with heterogeneous income. The aggregate crime rate now equals:

$$\tilde{C}(\bar{y}) = \int_{y_{min}}^{y_{max}} C(y,d)a(y)dy \tag{9}$$

where $a(y)$ is some symmetric distribution of y with median $\bar{y}$.[46]

Agents' utility function is:

$$U(y,d,p,j) = r(y+p-\tilde{C}(\bar{y})) - j - pf(d)\Omega - q(d)\tilde{C}(\bar{y})\tau\Omega \tag{10}$$

Proposition 8. *If j is uniformly distributed, then individuals' and societal doubt standards are identical regardless of whether criminals steal only from those with the same income, or if the effects of crime are evenly distributed throughout society. If j is normally distributed, however, then the reasonable doubt standard is lower if the effects of crime are evenly distributed throughout society.*

Proof: See Proof Appendix.

Proposition 8 depends on the the slope of $c(\cdot)$, which determines how effective lower values of $d(\bar{y})$ are at deterring crime. With a uniform distribution, this density is constant and the choice of d thus does not depend on how crime is distributed. With a normal distribution, poor agents, who commit more crime, are further to the right on the distribution where $c(\cdot)$ is larger and deterrence is more effective. The median voter, who is now affected by all crime, responds by choosing a lower $d(\bar{y})$ because it is more effective at deterring crime than when she is only threatened by criminals with the same income level.

The overall answer to how income heterogeneity affects the reasonable doubt standard is ambiguous. Suppose that a society consists of isolated neighborhoods where crime does not cross over between neighborhoods and each is homogeneous in income. Here, Proposition 7 shows that higher income heterogeneity causes a higher reasonable doubt standard. If neighborhoods are of highly

[46] Symmetry requires that the distribution of y is truncated from above.

mixed income, however, then crime is likely to cross income lines, and Proposition 8 suggests that, depending on the distribution of j, heterogeneity may instead induce a lower reasonable doubt threshold.

Our model may also be modified to assume that either the impact of crime or the risk of wrongful accusations are spread unevenly across income levels. It it plausible that poorer agents are more likely to be wrongfully accused, or that wealthy agents are more likely to be victims of property theft.[47] Depending on the exact distributional assumptions, allowing these effects may raise, lower, or not effect the reasonable doubt standard. We provide three brief examples:

1. Suppose that wrongful accusations are limited to only the poorest 1-49% of society. The remaining majority of agents will then prefer $d = 0$ because they themselves have no chance of being wrongfully convicted. Likewise, if crime victims are limited to the wealthiest $1-49\%$ of agents, then the majority will prefer $d = 1$ because they themselves suffer no loss from crime, and can thus costlessly seek to eliminate their risk of being wrongfully convicted.

2. Suppose that the conditions from Case 2 from Section 5.1 apply so that richer agents prefer a higher reasonable doubt standard. Further suppose that the richest $1 - 49\%$ of agents are immune from wrongful accusations which are instead evenly distributed across the rest of society. The median voter will respond to the resulting higher risk of wrongful accusation by choosing a higher reasonable doubt standard. Likewise, the same result occurs if the poorest $1 - 49\%$ of agents are immune from being crime victims. Here, the median voter suffers more from crime and thus chooses a higher d.

3. We considered an example where y is uniformly distributed and where the risk of wrongful accusation is a linear function of income: the poorest agent is twice as likely as the median agent to be wrongfully accused and the richest agent is at no risk at all. Here, because the median agent is unaffected, the societal reasonable doubt standard is also unchanged. The same outcome holds when we assume that the richest agent is twice as likely to be the victim of property theft as the median agent, and that the poorest agent is never victimized.

5.3 Civil Burdens of Proof

Many legal actions involving theft are pursued as civil matters rather than criminal prosecutions. The civil burden of proof differs in two important ways from the reasonable doubt standard. First, the preponderance of the evidence standard is unambiguously lower.[48] Second, because preponderance

[47] In the examples that follow, it does not matter if poorer agents are instead more likely to be crime victims.

[48] *In re Winship*, 397 U.S. at 371-372 (Harlan, J. concurring).

of the evidence is widely understood as greater than 50%, its quantitative meaning is made far clearer than that of reasonable doubt.

The first difference is easily explained by the well known idea that Blackstone's formulation is absent in civil cases, or at least is not as intense.[49] In our model, this implies a lower value of τ, which results in a lower threshold of proof.

The second difference may be explained by extending our model to civil cases by assuming that instead of incurring a punishment, Ω, a party either justly or wrongfully found liable must pay the victim one-unit, the amount of the theft. The utility function thus becomes:

$$U(y,d,p,j) = r\left(y + p(1-f(d)) - C(y)(1-f(d)) - (\tau-1)C(y)q(d)\right) - jip \tag{11}$$

If $\tau = 1$, then Blackstone's formulation does not apply. In this case, the cost of wrongful verdicts disappears from (11) because agents are as likely to benefit from a wrongful verdict as they are to suffer from one. This is reminiscent of Posner's (1998) argument that because a civil award transfers wealth from the accused to the victim instead of imposing a punishment that provides no tangible benefit to the victim, wrongful verdicts are much less concerning.[50] If the civil system resolves all cases, then the crime rate is:

$$C\left((1-f(d))r'(y)\right) \tag{12}$$

We assume $C(1)$, the crime rate for the poorest society with no risk of punishment is less than 50% so that potential criminals cannot affect the reasonable doubt standard. Differentiating (11) with respect to d yields agents' first-order condition:

$$C_d(\cdot)\left[f(d) - (\tau-1)q(d) - 1\right] + C(\cdot)\left[f_d(d) - (\tau-1)q_d(d)\right] = 0 \tag{13}$$

We next consider the widespread view that Blackstone's formulation does not apply to civil cases:[51]

[49] *Id.* at 371-372 (Harlan, J., concurring) ("the reason for different standards of proof in civil as opposed to criminal litigation [is that] [i]n a civil suit between two private parties for money damages...we view it as no more serious in general for there to be an erroneous verdict in the defendant's favor than for there to be an erroneous verdict in the plaintiff's favor. ... In a criminal case, on the other hand, we do not view the social disutility of convicting an innocent mas as equivalent to the disutility of acquitting someone who is guilty.")

[50] The U.S. Department of Education under President Obama made a similar argument for why U.S. colleges and universities should employ a preponderance of evidence standard when adjudicating allegations of sexual misconduct.

[51] Epps (2015) writes that "[Blackstone's formulation] makes the criminal sphere relatively unusual; for the most part, rules outside of the criminal context are not designed to skew errors asymmetrically. For example, in most civil cases the burden of persuasion is set at the preponderance of the evidence standard."

Proposition 9. *If $\tau = 1$, then all non-criminals, regardless of y, prefer the lowest possible reasonable doubt standard.*

Proof: See Proof Appendix.

We may interpret preponderance of the evidence as a corner solution where societies are choosing the lowest possible burden of proof. Proposition 9 may help explain why the civil burden of proof is explicitly quantified while the criminal burden is not. The choice of d in a civil case does not depend on income, and different communities may thus agree on a quantitative value. In contrast, the criminal burden of proof does, even if $\tau = 1$, and it is thus not quantified in order to allow different communities to choose their own values.

Another implication of Proposition 9 is that Blackstone's formulation must apply to civil cases in order to yield interior solutions where $d \approx \frac{1}{2}$. Evaluating (13) at $d = \frac{1}{2}$ shows that a necessary condition for $d \geq \frac{1}{2}$ is that $\tau \geq 2$.

We conclude by discussing the effect of y on the civil burden of proof if $\tau > 1$. In this case, the results mirror those of the criminal burden of proof. If we assume that j is uniformly distributed, then as y increases, $d(y)$ decreases. If j is normally distributed, however, then the two cases described in Section 5.1 are applicable to the civil setting as well.

6 Conclusion

The legal system's reluctance to clarify the definition of reasonable doubt is, at first glance, surprising. This paper has demonstrated that, whether by design or accident, this reluctance allows different communities to select different thresholds needed in order to convict. The relationship between income and the quantitative meaning of reasonable doubt is ambiguous, however. We identify cases where higher income may lead to either lower or high thresholds. Likewise, income heterogeneity may affect the threshold in different ways. Income heterogeneity increases the influence of potential criminals in the electoral process and may thus lead to a higher threshold. If crime spills over across income groups instead of remaining within income levels, however, then voters may find a lower threshold is more effective at deterring crime.

The threshold needed to convict is of interest to any party in a criminal trial, including the defense attorney, the prosecutor, and the accused. Our analysis has focused on only income's effect on reasonable doubt. It would be of interest to examine the impact of other demographic differences on the reasonable doubt threshold. Race, in particular, is worthy of additional study. Our model can be extended so that members of one racial group are more likely to be wrongfully accused if a crime is

committed by a fellow member of that group. Likewise, if different racial groups have different levels of income, we expect that they will be impacted by crime differently. The model can then examine how racial diversity affects the reasonable doubt threshold, and the rates of wrongful convictions in different groups. These questions are left for future research.

Proof Appendix

Proof of Proposition 1: Differentiating (7) with respect to τ yields $\frac{\partial^2 U(y,d,p,j)}{\partial d \partial \tau} = \frac{dr^{'}(y)z(\cdot)}{\tau^2} > 0$, requiring that larger values of d are necessary for Equation (7) to hold with equality. Furthermore, it is direct to verify that $d = 1$ satisfies Equation (7) as $\tau \to \infty$.

$\frac{\partial C(\cdot)}{\partial d} = dm(d)\Omega c(\cdot) > 0$, showing that the higher reasonable doubt threshold causes a higher crime rate. ■

Proof of Proposition 2: It follows from Equation (8) that:

$\frac{dr^{'}(y)}{\tau} < (1-d)\left(r^{'}(y) - \Omega f(d) - (\bar{j} - \frac{\delta}{2})\right)$.

Re-arranging:

$d < \frac{1}{1+\frac{r^{'}(y)}{\tau\left(r^{'}(y) - \Omega f(d) - (\bar{j} - \frac{\delta}{2})\right)}}$

Because $\frac{r^{'}(y)}{r^{'}(y) - \Omega f(d) - (\bar{j} - \frac{\delta}{2})} \geq 1$, it then follows that for $\tau = 1$, $d < \frac{1}{2}$. ■

Proof of Proposition 3: Differentiating (8) with respect to y yields:

$$\frac{\partial^2 U(y,p)}{\partial d \partial y} = \frac{\partial r^{'}(y)}{\partial y}\left(1 - d - \frac{d}{\tau}\right) \tag{14}$$

By the concavity of $r(\cdot)$, $\frac{\partial r^{'}(y)}{\partial y} < 0$. For (14) to ever be non-negative, it must be the case that $d \geq \frac{1}{1+\tau^{-1}}$. Proposition 2, however, establishes that $d < \frac{1}{1+\tau^{-1}}$. It follows that $\frac{\partial^2 U(y,p)}{\partial d \partial y} < 0$ and that the reasonable doubt threshold is decreasing in income. It is then direct from (5) that $C(y)$ is also decreasing in y. ■

Proof of Proposition 4: Differentiating (8) with respect to Ω yields:

$$\frac{\partial^2 U(y,p)}{\partial d \partial \Omega} = -(1-d)f(d) - dq(d) < 0 \tag{15}$$

It is then direct from (5) that $C(y)$ also declines. ■

Proof of Proposition 5: Differentiating (7) with respect to y, yields:

$$\frac{\partial^2 U}{\partial d \partial y} = \frac{\partial r^{'}(y)}{\partial y}\left[-\frac{dc(\cdot)}{\tau} - dr^{'}(y)c^{'}(\cdot)\tau^{-1} + (1-d)c(\cdot) - d\Omega c^{'}(\cdot)\int_d^1 (1-g)m(g)dg\right] \tag{16}$$

Dividing through by $\frac{\partial r^{'}(y)}{\partial y}$ which is negative, $d(y)$ is increasing in y if and only if:

$$\frac{dc(\cdot)}{\tau} + dr^{'}(y)c^{'}(\cdot)\tau^{-1} - (1-d)c(\cdot) + d\Omega c^{'}(\cdot)\int_{d}^{1}(1-g)m(g)dg > 0 \tag{17}$$

we then eliminate $c(\cdot)$ using the properties of the normal distribution where $c^{'}(\cdot) = xc(\cdot)$ and x is the number of standard deviations below the mean of $C(\cdot)$. Equation (17) then becomes:

$$\frac{d}{\tau} + \frac{xdr^{'}(y)}{\tau} - (1-d) + xd\Omega\int_{d}^{1}(1-g)m(g)dg > 0 \tag{18}$$

As $x \to \infty$, $C(y) \to 0$. For large enough x, the sign of (18) is determined by $\frac{xdr^{'}(y)}{\tau} + xd\Omega\int_{d}^{1}(1-g)m(g)dg$ which is always greater than zero. It thus follows for low enough crime rates, the reasonable doubt threshold is increasing in income. ■

Proof of Proposition 6: As $d \to 0$, the left-hand side from (18) approaches $-(1-d)$. If $d(1)$ is sufficiently low, then it follows that as y increases, $d(y)$ initially decreases, and the crime rate falls. It is then direct that the left-hand side of (18) equals zero for some x, and becomes positive for higher values of x. Higher values of y then lead to higher values of $d(y)$ and, from (7), as $y \to \infty$, $d(y) \to 1$.■

Proof of Proposition 7: Denoting $d(\bar{y})$ as the doubt standard for the homogeneous society, there exists some j that is sufficiently high so that $p(\bar{y}, d(\bar{y}), j) = 1$. The first-order condition for such a potential criminal is:

$$\frac{d}{\tau} - \frac{dr^{'}(y)c(\cdot)}{\tau} + (1-d)C(\cdot)) - d\Omega c(\cdot)\int_{d}^{1}(1-g)m(g)dg = 0 \tag{19}$$

Equation (18) differs from (7) only in the inclusion of $\frac{d}{\tau}$. It thus follows that some potential criminals with the median income prefer a higher d.

Suppose $d(y)$ is a monotonic function of y. With a heterogeneous society, the mass of agents with thresholds lower than $d(\bar{y})$ is smaller than the mass of agents with a higher threshold because the latter includes potential criminals with high doubt thresholds. It then follows that the median doubt level is greater than $d(\bar{y})$.

If $d(y)$ is not a monotonic function of y, then the support of y must include the region described by Case 2 in Section 5.1 where $d(y)$ is minimized. In this case, the mass of agents with a higher doubt threshold is even larger relative to the mass of agents with smaller doubt thresholds. Again, the median doubt level is greater than $d(\bar{y})$.

It is direct that $\frac{\partial C(y)}{\partial d} > 0$. Twice-differentiating, $\frac{\partial^2 C(y)}{\partial y^2} = \frac{\partial^2 r^{'}(y)}{\partial y^2} c(\cdot) + \left(\frac{\partial r^{'}(y)}{\partial y}\right)^2 c^{'}(\cdot)$. The crime rate is thus convex in y as long as $c^{'}(\cdot) \geq 0$, which is true for both uniform and normal distributions for $C(y) < \frac{1}{2}$. The heterogeneous society thus has a higher crime rate both because it has a higher doubt standard, and because as we move below $\bar{y}$, the crime rate rises at least as fast as it falls when we move above $\bar{y}$. ■

Proof of Proposition 8: The only term that is affected in Equation (6) is $\tilde{C}_d(y)$:

$$-r^{'}(y)\tilde{C}_d(y) - \tau\Omega C(y) q_d(d) - \tau\Omega\tilde{C}_d(y) q(d) = 0 \tag{20}$$

where:

$$\tilde{c}_d(y) = d\Omega m(d) \int_{y_{min}}^{y_{max}} c(r^{'}(y) - \Omega f(d)) a(y) dy \tag{21}$$

For a uniform distribution, $c(\cdot)$ is constant for all income levels, $\tilde{C}_d(y) = C_d(y)$ for all y, and all agents have the same reasonable doubt preferences. For normal distributions, the convexity of $r^{'}(y)$ and the property that $c^{'}(\cdot) > 0$ for all crime rates less than one-half, ensures that $\tilde{C}_d(y) > C_d(y)$. It then follows from (20) that agents choose a lower reasonable doubt threshold. ■

Proof of Proposition 9: From (2), $f_d(d) < 0$, and $f(d) \leq 1$, and from (12), $C_d(\cdot) > 0$. It then follows that (13) is less than zero for all d and that a corner solution exists where $d(y) = 0$. for all y. ■

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