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Do Less-Violent Technologies Result in Less Violence? A Theoretical Investigation Applied to the Use of Tasers by Law Enforcement

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Abstract

The use of a taser by law enforcement can substitute for either a gun (a more-violent technology) or a mildly-violent technology (such as pepper spray or hands-on tactics). Which is used affects both the severity of harm when used and the amount of resistance, which affects how often it must be used. Thus, does the adoption of a less-violent technology lead to more or less violence? This question is addressed in an application to the adoption of tasers by law enforcement officials. A game-theoretic model is developed and environments where resistance to arrest and expected harm both increase and decrease are identified.

JEL: K42

Keywords: Law enforcement; less-violent technology; strategic offsetting behavior

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1 Introduction

On March 20, 2008 a teenager, Darryl Turner, was caught by his mother shoplifting from a local grocery store in Charlotte, NC. Darryl returned the item to the grocery store and, subsequently, a verbal fight broke out between the store manager and the teen. A law enforcement official responded to the disturbance and requested him to cease (Cherrie 2008). Darryl stepped towards the officer and walked past him. The officer used his taser on Darryl for approximately thirty-seven consecutive seconds and then, on the ground, tasered him for another five seconds. Darryl was pronounced dead soon after with cardiac arrest (Wootson 2008).¹

It is commonly argued that the adoption and use of tasers by law enforcement is positive (Hougland, Mesloh, and Henych 2005). It is less harmful than a gun if used and is extremely successful at resolving the conflict. As the event illustrates, this commonly held opinion may not necessarily be accurate. It is argued that tasers, being classified as a “less-lethal technology” (Hubbs and Klinger 2004) are occasionally inappropriately used (Editorial 2008). Perceptions of them being less violent may lead to their excessive use and, coupled with their potential harm, may in fact lead to more violence (Lacour 2008).

This event and the ensuing debate illustrate the question addressed by this paper. Does a new, less-violent technology lead to more violence or less violence? To address this question I build a theoretical model of the interaction between a criminal and a law enforcement official. The criminal chooses to either resist arrest or not and the enforcement official selects a technology to resolve the conflict and make the arrest. Such a conflict is inherently strategic. The criminal’s well-being if resisting arrest depends on the technology used and the enforcement official’s selection of technology depends on the likelihood that it needs to be used. The objective is to identify the

¹As of July 21, 2008, the law enforcement official will not be prosecuted for the event. An internal affairs investigation of the Charlotte-Mecklenburg Police Department, though, found that the initial discharge of the taser was within procedures, but the prolonged use was not. This resulted in a five-day, unpaid suspension (Wootson 2008).

environments in which the adoption of the less-violent technology is beneficial along with the environments in which it is not.

One may think of the model as an extension of the “offsetting behavior hypothesis” (Peltzman 1975). As one reduces either the probability of harm or the size of the loss, the incentives to take precautionary actions are reduced. This results in an offsetting behavior that mitigates the benefit to the new technology. This idea has been developed, tested, and applied to automobile safety regulation² (Peltzman 1975; Crandall and Graham 1984; Chirinko and Harper 1993), seatbelts (Risa 1994), airbag-equipped cars (Peterson et al. 1995), safety equipment in NASCAR (O’Roark and Wood 2004; Sobel and Nesbit 2007), workplace safety investments (Viscusi 1979), and child-resistant bottle caps (Viscusi 1984). The analysis here introduces and investigates a “strategic offsetting behavior”. While the availability of the new technology may affect the official’s behavior, as in the offsetting behavior hypothesis, its availability also influences the criminal’s behavior, as a strategic effect. Additionally, the work presented here differs from this literature in that the new technology substitutes for both a more violent and less violent one, rather than just being a safer option than the previous technology.

A taser is a common name for a conducted energy device (CED).³ CEDs use a low-power, high-voltage charge of electricity to induce involuntary muscle contractions leading to temporary incapacitation (NIJ Special Report 2008). There are 11,500 law enforcement agencies who have acquired CEDs, which is approximately 260,000 devices (NIJ Special Report 2008). Since 2001 there have been 291 taser-related deaths nationwide (Amnesty International 2007). Therefore, given their widespread adoption and potential for harm, it is important to understand the impact on the amount

²The 1968 standards implemented by the National Highway and Traffic Safety Administration included seatbelts, energy-absorbing steering column, penetration-resistant windshield, dual braking system, and padded instrument panel (Peltzman 1975).

³Taser stands for Thomas A. Swift’s Electronic Rifle (Hougland, Mesloh, and Heynch 2005) and is produced by Taser International. Other common names for CEDs are stun guns and Stingers (Adams and Jennison 2007).

of violence. There are a few empirical studies on the effects of tasers. Smith, Petrocelli, and Scheer (2007) study court cases of taser-related excessive force litigation and conclude that while courts routinely approve of their use, agencies should review guidelines to remain compliant with legal standards. Smith et al. (2007) analyze data on officer and suspect injuries from two law enforcement agencies and show that at one agency the adoption of tasers reduced the odds of injury, while at the other agency there was no relationship. Adams and Jennison (2007) review literature, agency reports, and media information and illustrate that there is much variation in training, deployment, and policies. They identify the tradeoff between less violence due to less use of deadly force and more violence due to additional use with the adoption of tasers. Thus, one may think of the formal work here as identifying the conditions in which their downgrade replacement and upgrade replacements occurs. White and Ready (2008) examine all taser-related incidence involving NYPD officers between 2002 and 2005 identifying the determinants of taser effectiveness. Fish and Geddes (2001) summarize medical findings and conclude that, while much research needs to be done on their effect, properly used tasers are less likely than guns to cause injury and death of the target and the police officer. Vike and Chan (2007) also summarize medical research on CEDs and argue that the possibility of life-threatening effects of tasers is low. Therefore, the analysis of the strategic considerations done here complements the empirical and medical research on the effect of the adoption of less-violent technologies.

Section 2 presents the game-theoretic model. Section 3 analyzes the predictions of the model with only two technologies and with three technologies. It should be pointed out that while this paper considers a gun, a taser, and pepper spray any technologies can substitute into the analysis. Pepper spray represents any mildly-violent technology, which can be, for example, the use of no weapon (hands-on tactics).⁴ The

⁴In fact, a National Institute for Justice report considers the impact of the adoption of pepper spray by North Carolina police substituting for other technologies that are more and less violent (NIJ Research for Practice 2003).

taser represents any technology that results in an intermediate amount of violence, or rather, “an instrument of force in the continuum between . . . verbal commands and deadly force” (Hubbs and Klinger 2004, 61). Section 4 discusses policy implications and concludes.

2 Model

The objective is to develop a straightforward model of the choice to resist and the choice of weapon use. Thus, consider a game with two players: a criminal, C_i , and a law enforcement official, E . E arrives on the scene of a crime committed by C_i . The criminal selects whether to resist arrest, R , or not, NR . Hence, one may think of the model as one of “active resistance” (Zigmund 2007). E chooses a technology to use to suppress the criminal and make the arrest. Let X denote the set of technologies available to E . Assume that each player’s selection occurs without knowledge of the other player’s selection.⁵ This, then, does not consider any potential deterrent effect, but rather considers a criminal’s resistance decision based on (expected) suppression.

The criminal’s payoff is zero if he does not resist arrest. This simplification implies that the payoff received if resisting arrest is to be thought of as that gained beyond what is received if he was compliant. If C_i does resist arrest there are two components to his payoff function. A benefit b_i is gained by criminal C_i . The value of b_i is drawn from a uniform distribution over $[0, B]$. C_i knows his value of b_i prior to making the choice of R or NR , while E knows only the distribution of potential benefits. One may think of this benefit as capturing any gains C_i perceives from resisting arrest (e.g. psychological benefits) – any motivation he may have for resisting arrest. If technology j is used to suppress C_i an expected harm of h_j is incurred (e.g. expected bodily injury). Thus, if R is selected by C_i , then a payoff of $b_i - h_j$ is received if technology j is used to resolve the conflict.

There are two components to E ’s payoff. E receives an expected benefit of a_j by

⁵Section 4 discusses and considers extensions to the model including the sequencing of actions.

attempting to arrest a resisting criminal. For simplicity, assume that it is the same regardless of whether C_i resists arrest and that it depends on the technology used. The value of a_j reflects considerations such as the likelihood of successfully apprehending the criminal (which is likely greatest with a violent technology such as a gun) and any financial, career, and psychological benefits she may receive. Using technology j exposes her to a liability l_j . This liability may include, for examples, expected legal liability⁶, expected lost pay due to a suspension, and any emotional internalization of the harm caused by the use of technology j . It is important to emphasize that the components of the players' payoff functions can incorporate any benefit and cost to using a particular technology and resisting arrest. This includes uncertain outcomes and perceived gains. Furthermore, regardless of the benefit to resisting arrest and the potential for harm, with a small, exogenous probability the criminal resists arrest. Let $1 - \lambda \in [0, 1)$ denote this probability. Hence, with probability $1 - \lambda$ C_i selects R , while with probability λ C_i selects his best response. This generalization allows for the consideration of an irrational proportion of the population who simply do not respond to the enforcement official or her choice of technology.

3 Analysis

To analyze the effect of the adoption of a less-violent technology the game with two technologies, $X_2 = \{P, G\}$, is contrasted to the game with three technologies, $X_3 = \{P, T, G\}$. One may think of P representing the use of pepper spray, hands-on tactics, or any mildly-violent technology, T representing a taser, and G representing a gun (a potentially lethal and violent technology). Assume that $h_g > h_t > h_p > 0$, and $l_g > l_t > l_p \geq 0$. This describes an environment where the violent technology has the potential to cause more harm and exposes the enforcement official to more

⁶The Supreme Court in *Graham v. Connor* (1989), articulated an “objective reasonableness” standard for excessive force. Zigmund (1989) surveys court cases that involved tasers to identify when a law enforcement officer can lawfully use a taser. He concludes that medical information is lacking and case law regarding negligence is unclear.

potential liability and harm.

3.1 Two Technologies, $X = X_2$

Consider the 2x2 game between C_i and E . Let σ denote the probability that C_i resists arrest from E 's perspective given the E does not know the realization of b_i . Let γ denote the probability that E uses the technology G . Consider C_i 's selection. While the utility of selecting NR is zero, the expected utility of selecting R is $Eu(R) = b_i - \gamma h_g - (1 - \gamma) h_p = b_i - h_p - \gamma (h_g - h_p)$. Therefore, for a sufficiently great value of b_i C_i chooses to resist arrest, while for low values of b_i he chooses to not resist. The threshold value is

$$b^* = h_p + \gamma (h_g - h_p). \quad (1)$$

Assume that $B > h_g$ so that there is a positive probability that a criminal prefers to resist. Hence, the best response for a criminal with $b_i < b^*$ is to not resist arrest, while the best response for a criminal with $b_i > b^*$ is to resist. With probability λ the criminal chooses his best response and, conditional on doing so, has such a high benefit with probability $1 - \frac{b^*}{B}$. As a consequence,

$$\sigma = 1 - \frac{\lambda b^*}{B}. \quad (2)$$

Additionally, since $B > h_g > h_p > 0$ and $\lambda \in (0, 1]$, $\sigma \in (0, 1)$. Now consider E 's selection. Her expected utility with technologies j is

$$Eu(j) = \sigma (a_j - l_j) + (1 - \sigma) a_j = a_j - \sigma l_j. \quad (3)$$

Define $r_{gp} = \frac{a_g - a_p}{l_g - l_p}$ as the ratio of the surplus generated by selecting G rather than P to make the arrest relative to the additional liability. Thus, it follows from (3) that if $\sigma > r_{gp}$, then $Eu(P) > Eu(G)$, while if $\sigma < r_{gp}$, then G is the best response for E . The following proposition provides the pure strategy equilibria in the game. If the surplus generated by selecting G , $a_g - a_p$, is great relative to the additional liability, $l_g - l_p$, then it is best for the enforcement official to use a gun. Alternatively, if the

surplus generated by choosing G is small (or negative) relative to the liability, then it is best to choose the less-violent technology.

Proposition 1 *If $r_{gp} > 1 - \frac{\lambda h_g}{B}$, then an equilibrium outcome is $\gamma^g = 1$ and $\sigma^g = 1 - \frac{\lambda h_g}{B}$. If $r_{gp} \leq 1 - \frac{\lambda h_p}{B}$, then an equilibrium outcome is $\gamma^p = 0$ and $\sigma^p = 1 - \frac{\lambda h_p}{B}$.*

Proof. γ^g is a best response for E since $\sigma \leq r_{gp}$. At $\gamma = \gamma^g$ it follows from (1) that $b^* = h_g$. Therefore, C_i 's best response is R if $b_i > h_g$ and NR if $b_i < h_g$. Hence, $\sigma = 1 - \frac{\lambda h_g}{B}$ ($= \sigma^g$). Therefore, if $r_{gp} \geq 1 - \frac{\lambda h_g}{B}$, then $\gamma = \gamma^g$ and $\sigma = \sigma^g$ is a equilibrium outcome. A similar analysis shows that if $r_{gp} \leq 1 - \frac{\lambda h_p}{B}$, then $\gamma = \gamma^p$ and $\sigma = \sigma^p$ is a equilibrium outcome. ■

Therefore, if the benefit to attempting the arrest is significantly greater using G , relative to the additional liability, then the enforcement official uses the gun. Alternatively, if the benefit to using G is small, relative to the added liability, then she uses the pepper spray. For intermediate values of r_{gp} a coordination game arises. If the enforcement officer uses the violent technology, then most criminals prefer to not resist arrest. If many criminals are not resisting, then the additional cost of using the violent technology is not incurred. Alternatively, if many criminals do choose to resist arrest, then it is in the best interest of the enforcement official to not use the violent technology if the gain to using it does not adequately compensate her for the additional liability. If the violent technology is not used, then many criminals find it best to resist arrest. Like any coordination game, then, there exists an additional equilibrium in mixed strategies.

Proposition 2 *Suppose $r_{gp} \in \left[1 - \frac{\lambda h_g}{B}, 1 - \frac{\lambda h_p}{B}\right]$. An equilibrium outcome is $\sigma^m = r_{gp}$ and $\gamma^m = \frac{B(1-r_{gp})-\lambda h_p}{\lambda(h_g-h_p)}$.*

Proof. At $\sigma = \sigma^m$ $Eu(P) = Eu(G)$ so that $\gamma = \gamma^m$ is a best response for E since $\gamma^m \in [0, 1]$ if $r_{gp} \in \left[1 - \frac{\lambda h_g}{B}, 1 - \frac{\lambda h_p}{B}\right]$. At $\gamma = \gamma^m$ it follows from (1) that $b^* = h_p + \gamma^m (h_g - h_p)$. Therefore, C_i 's best response is R if $b_i > h_p + \gamma^m (h_g - h_p)$

and NR if $b_i < h_p + \gamma^m (h_g - h_p)$. Hence, $\sigma = 1 - \frac{\lambda[h_p + \gamma^m(h_g - h_p)]}{B}$, which simplifies to $\sigma = r_{gp}$ ($= \sigma^m$). Therefore, if $r_{gp} \in \left[1 - \frac{\lambda h_g}{B}, 1 - \frac{\lambda h_p}{B}\right]$, then $\gamma = \gamma^m$ and $\sigma = \sigma^m$ is an equilibrium outcome. ■

3.2 Three Technologies, $X = X_3$

Now consider the model with the strategy set for E of $X_3 = \{P, T, G\}$. As before, let σ denote the probability that E 's opponent selects R and let γ denote the probability that E selects G . Define τ as the probability that E selects T . Therefore, the probability that E chooses P is now $1 - \tau - \gamma$. The expected utility to C_i of selecting NR is still 0, while selecting R is $Eu(R) = b_i - \gamma h_g - \tau h_t - (1 - \tau - \gamma) h_p = b_i - h_p - \tau (h_t - h_p) - \gamma (h_g - h_p)$. As before, there exists a threshold value of b_i in which a criminal with $b_i > b^*$ prefers R , while a criminal with $b_i < b^*$ selects NR as a best response. It follows that

$$b^* = h_p + \tau (h_t - h_p) + \gamma (h_g - h_p). \quad (4)$$

Consequently, $\sigma = 1 - \frac{\lambda b^*}{B}$ as in (2). E 's expected utility using technology j remains $Eu(j) = \sigma (a_j - l_j) + (1 - \sigma) a_j = a_j - \sigma l_j$. As before, define r_{ij} as the ratio of the surplus generated from arrest, $a_i - a_j$, over the additional liability, $l_i - l_j$. Again, if $\sigma > r_{gp}$, then $Eu(P) > Eu(G)$, while if $\sigma < r_{gp}$, then $Eu(P) < Eu(G)$. Additionally, if $\sigma > r_{gt}$, then the expected utility from T exceeds that using G and if $\sigma < r_{tp}$, then using T generates a greater expected utility than P .

If using G generates a greater gain than using both T and P , relative to the additional liability incurred, then there exists a pure strategy equilibrium where E selects G . If the gain to selecting G and T is small, relative to the additional liability, then E prefers to choose P . Alternatively, if T is a significant gain over P and does not lose much relative to G , then there is a pure strategy equilibrium where the enforcement official uses T .

Proposition 3 *If $\max\{r_{gp}, r_{tp}\} \leq 1 - \frac{\lambda h_p}{B}$, then an equilibrium outcome is $\gamma^p = \tau^p = 0$ and $\sigma^p = 1 - \frac{\lambda h_p}{B}$. If $\min\{r_{gp}, r_{gt}\} \geq 1 - \frac{\lambda h_g}{B}$, then an equilibrium outcome is*

$\gamma^g = 1$ and $\sigma^g = 1 - \frac{\lambda h_g}{B}$. If $1 - \frac{\lambda h_t}{B} \in [r_{gt}, r_{tp}]$, then an equilibrium outcome is $\tau^t = 1$ and $\sigma^t = 1 - \frac{\lambda h_t}{B}$.

Proof. $\gamma^p = \tau^p = 0$ is a best response for E since $\sigma \geq r_{gp}$ and $\sigma \geq r_{tp}$. At $\gamma^p = \tau^p = 0$ it follows from (4) that $b^* = h_p$. Therefore, C_i 's best response is R if $b_i > h_p$ and NR if $b_i < h_p$. Hence, $\sigma = 1 - \frac{\lambda h_p}{B}$ ($= \sigma^p$). Therefore, if $\max\{r_{gp}, r_{tp}\} \leq 1 - \frac{\lambda h_p}{B}$, then $\gamma^p = \tau^p = 0$ and $\sigma = \sigma^p$ is an equilibrium outcome. A similar analysis verifies the existence of the remaining equilibria. ■

Along with the three pure strategy equilibria there exist environments where mixed strategy equilibria exist in which R and NR are played with a positive probability and two of the technologies are used with a positive probability by E .⁷

Proposition 4 *If $r_{gp} \in \left[\max\left\{r_{tp}, 1 - \frac{\lambda h_g}{B}\right\}, \min\left\{r_{gt}, 1 - \frac{\lambda h_p}{B}\right\} \right]$, then $\sigma^{gp} = r_{gp}$, $\gamma^{gp} = \frac{B(1-r_{gp})\lambda h_p}{\lambda(h_g-h_p)}$, and $\tau^{gp} = 0$ is an equilibrium outcome. If $r_{tp} \in \left[\max\left\{r_{gt}, r_{gp}, 1 - \frac{\lambda h_t}{B}\right\}, 1 - \frac{\lambda h_p}{B} \right]$, then $\sigma^{tp} = r_{tp}$, $\gamma^{tp} = 0$, and $\tau^{tp} = \frac{B(1-r_{tp})-\lambda h_p}{\lambda(h_t-h_p)}$ is an equilibrium outcome. If $r_{gt} \in \left[1 - \frac{\lambda h_g}{B}, \min\left\{r_{gp}, r_{tp}, 1 - \frac{\lambda h_t}{B}\right\} \right]$, then $\sigma^{gt} = r_{gt}$, $\gamma^{gt} = \frac{B(1-r_{gt})-\lambda h_t}{\lambda(h_g-h_t)}$, and $\tau^{gt} = 1 - \gamma^{gt}$ is an equilibrium outcome.*

Proof. $\gamma = \gamma^{gp}$ and $\tau = \tau^{gp}$ is a best response for E as long as $\sigma \leq r_{gt}$ and $\sigma \geq r_{tp}$. Also, $\gamma^{gp} \in [0, 1]$ if $r_{gp} \in \left[1 - \frac{\lambda h_g}{B}, 1 - \frac{\lambda h_p}{B} \right]$. At $\gamma = \gamma^{gp}$ and $\tau = \tau^{gp} = 0$ it follows from (4) that $b^* = h_p + \gamma^{gp}(h_g - h_p)$. Therefore, C_i 's best response is R if $b_i > h_p + \gamma^{gp}(h_g - h_p)$ and NR if $b_i < h_p + \gamma^{gp}(h_g - h_p)$. Hence, $\sigma = 1 - \frac{\lambda[h_p + \gamma^{gp}(h_g - h_p)]}{B}$, which simplifies to $\sigma = r_{gp}$ ($= \sigma^{gp}$). Therefore, if $r_{gp} \in \left[\max\left\{r_{tp}, 1 - \frac{\lambda h_g}{B}\right\}, \min\left\{r_{gt}, 1 - \frac{\lambda h_p}{B}\right\} \right]$, then $\sigma^{gp} = r_{gp}$, $\gamma^{gp} = \frac{B(1-r_{gp})\lambda h_p}{\lambda(h_g-h_p)}$, and $\tau_{gp} = 0$ is an equilibrium outcome. A similar analysis verifies the existence of the remaining equilibria. ■

⁷A mixed strategy equilibrium where all three technologies are used with a positive probability occurs only if r_{gp} , r_{gt} , and r_{tp} all exactly equal each other. This unlikely scenario is not considered.

3.3 Effect of the New Technology

Now turn to a comparison of the outcomes derived with X_2 and X_3 as the set of possible technologies available to the law enforcement official. One variable policymakers are likely interested in is the effect the adoption of a less-violent technology has on the rate at which criminals resist arrest. Resisting arrest opens up the possibility of injury to the enforcement official and third parties. If the existence of the taser results in a lower fraction of the population choosing to resist arrest, then it can be argued that the adoption of the technology is good.

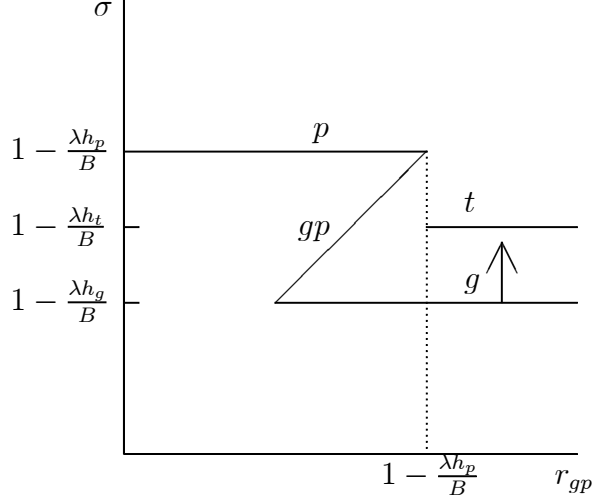
If the ratio is rather high, $r_{gp} > 1 - \frac{\lambda h_p}{B}$, then it follows from Propositions 1 and 2 that if there is only two technologies available, then the enforcement official uses the gun to arrest the criminal in the unique equilibrium. This leads to a low rate of resistance to arrest on the part of the criminal. What happens in this environment if the taser is available as well?

It follows from Proposition 3 that the pure strategy equilibrium where E selects P and from Proposition 4 the mixed strategy equilibrium where P and G are chosen are still not outcomes of the game. Notice that from Proposition 3 the outcome where G is used as a pure strategy is an equilibrium only if $r_{gt} \geq 1 - \frac{\lambda h_g}{B}$ as well. Suppose that this inequality did not hold, or rather, the gain using the gun in the arrest (rather than the taser) is not that great compared to the additional liability using the gun (rather than the taser) imposes. This environment seems reasonable; both the gun and the taser effectively suppress the criminal, but there is a substantial difference in liability. In such a case another equilibrium is selected. All remaining equilibria involve the use of T . Figure 1 depicts the shift in the rate of resistance if the third, less-violent technology is available.⁸

As one can see, the probability that the criminal resists arrest increases. The existence of a less-violent technology results in the enforcement official using it rather than the more-violent technology. Consequently, since the harm if resisting arrest

⁸Figures 1 and 2 illustrate the shift to the equilibrium with $\tau^t = 1$.

Figure 1: Increase in the Rate of Resistance



diminishes, more resistance arises. The following result provides environments in which the adoption of the new technology leads to more conflict.

Result 1 If $r_{gp} > 1 - \frac{\lambda h_p}{B} > r_{gt}$, then in equilibrium σ is strictly greater if $X = X_3$ than if $X = X_2$.

Proof. From Propositions 1 and 2 if $r_{gp} > 1 - \frac{\lambda h_p}{B}$, then the unique equilibrium outcome is $\sigma = \sigma^g = 1 - \frac{\lambda h_g}{B}$ if $X = X_2$. From Propositions 3 and 4 if $r_{gp} > 1 - \frac{\lambda h_p}{B} > r_{gt}$, then σ^p , σ^g , and σ^{gp} are not equilibria outcomes. Additionally, $\sigma^t = 1 - \frac{\lambda h_t}{B} > 1 - \frac{\lambda h_g}{B}$, $\sigma^{tp} (= r_{tp})$ is an equilibrium outcome only if $r_{tp} \in [1 - \frac{\lambda h_t}{B}, 1 - \frac{\lambda h_p}{B}]$, and $\sigma^{gt} (= r_{gt})$ is an equilibrium outcome only if $r_{gt} \in [1 - \frac{\lambda h_g}{B}, 1 - \frac{\lambda h_t}{B}]$. Hence, regardless of which is selected $\sigma > 1 - \frac{\lambda h_g}{B} = \sigma^g$ if $X = X_3$. ■

Thus, it is possible that adopting a new technology leads to more resistance and, therefore, more opportunities for harm. There is a strategic offsetting behavior. At the same time, though, the harm caused to the criminal who is resisting arrest is less. What is the net effect on the expected harm caused? The harm is incurred only if the criminal resists arrest. Therefore, the expected harm if G is used is $\sigma^g h_g = (1 - \frac{\lambda h_g}{B}) h_g$. With $X = X_3$ if $r_{gp} > 1 - \frac{\lambda h_p}{B} > r_{gt}$, then all equilibria involve

the use of T . Suppose that the equilibrium outcome of $\tau_t = 1$ arises.⁹ The expected harm with the new, less-violent technology becomes $\sigma^t h_t = \left(1 - \frac{\lambda h_t}{B}\right) h_t$. It follows that $\sigma^g h_g$ is less than $\sigma^t h_t$ if

$$h_g + h_t > \frac{B}{\lambda}. \quad (5)$$

Thus, if (5) holds, then the adoption of tasers leads to a strategic offsetting behavior where a greater expected harm is inflicted.

Result 2 Suppose $r_{gp} > 1 - \frac{\lambda h_p}{B} > r_{gt}$ and $r_{gp} > r_{tp}$. If $h_g + h_t > \frac{B}{\lambda}$, then the expected harm is greater with $X = X_3$ than $X = X_2$. Otherwise, it is less.

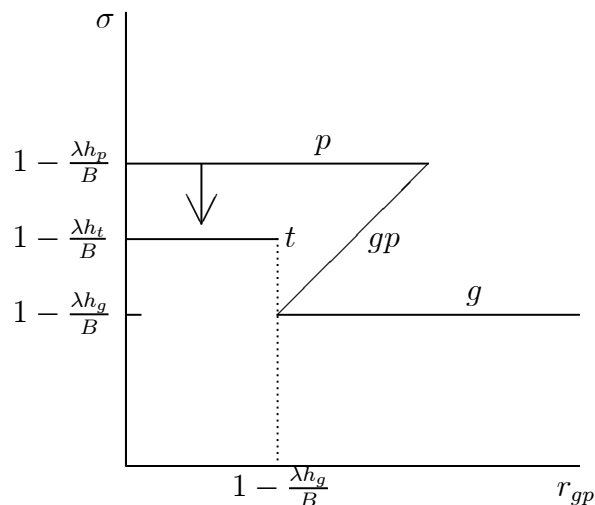
Proof. From the proof of Result 1 if $r_{gp} < 1 - \frac{\lambda h_g}{B} < r_{tp}$, then σ^g is the unique equilibrium outcome if $X = X_2$ and σ^{tp} , σ^{gt} , and σ^t are the equilibrium outcomes if $X = X_3$. The expected harm if $X = X_2$ is $\sigma^g h_g = \left(1 - \frac{\lambda h_g}{B}\right) h_g$, while if $r_{gp} > r_{tp}$ then σ^t is selected and the expected harm if $X = X_3$ with σ^t is $\sigma^t h_t = \left(1 - \frac{\lambda h_t}{B}\right) h_t$. It follows that the former is less if (5) holds. ■

Thus, if the taser causes a significant amount of harm, then its adoption results in a greater expected harm. If the gun causes a significant amount of harm, then the additional resistance that arises when enforcement officers switch to tasers results in more harm being experienced. Additionally, if the proportion of the criminals that are irrational is low (high λ) and the number of criminals with a high value to resisting arrest is small (low B), then the adoption of the less-violent technology increases the expected harm since few criminals would resist arrest if the taser wasn't available.

Second, it follows from Propositions 1 and 2 that if $r_{gp} < 1 - \frac{\lambda h_g}{B}$, then if there is only two technologies available the enforcement official uses the pepper spray to resolve the conflict. This leads to a high rate of resistance to arrest on the part of the criminal. What happens in this environment if the taser is available as well?

⁹To simplify the analysis attention is restricted to the equilibrium where T is selected as a pure strategy. All equilibria share the same qualitative feature that the harm expected is less (greater) than $G(P)$, but the probability of that harm arising is greater (less) than $G(P)$.

Figure 2: Decrease in the Rate of Resistance



As before, it follows from Propositions 3 and 4 that the pure strategy equilibrium where E chooses G and the mixed strategy equilibrium where P and G are selected with a positive probability are not outcomes if $r_{gp} < 1 - \frac{\lambda h_g}{B}$. From Proposition 3 the outcome where P is used as a pure strategy is an equilibrium only if $r_{tp} \leq 1 - \frac{\lambda h_p}{B}$ as well. Suppose that this inequality did not hold, or rather, the value to using the taser in the arrest (rather than pepper spray) is not that great compared to the additional liability using a taser imposes. In such a case another equilibrium is selected. All remaining potential equilibrium involve the use of T . Figure 2 depicts the shift in the rate of resistance if the third, less-violent technology is available.

The probability that the criminal resists arrest decreases. The existence of a less-violent technology results in the enforcement official using it rather than the mildly-violent technology. Consequently, since the harm if resisting arrest escalates, less resistance occurs.

Result 3 If $r_{gp} < 1 - \frac{\lambda h_g}{B} < r_{tp}$, then in equilibrium σ is strictly less if $X = X_3$ than if $X = X_2$.

Proof. From Propositions 1 and 2 if $r_{gp} < 1 - \frac{\lambda h_g}{B}$, then the unique equilibrium outcome is $\sigma = \sigma^p = 1 - \frac{\lambda h_p}{B}$ if $X = X_2$. From Propositions 3 and 4 if $r_{gp} < 1 - \frac{\lambda h_g}{B} <$

r_{tp} , then σ^g , σ^p , and σ^{gp} are not equilibria outcomes. Additionally, $\sigma^t = 1 - \frac{\lambda h_t}{B} < 1 - \frac{\lambda h_p}{B}$, σ^{tp} ($= r_{tp}$) is an equilibrium outcome only if $r_{tp} \in \left[1 - \frac{\lambda h_t}{B}, 1 - \frac{\lambda h_p}{B}\right]$, and σ^{gt} ($= r_{gt}$) is an equilibrium outcome only if $r_{gt} \in \left[1 - \frac{\lambda h_g}{B}, 1 - \frac{\lambda h_t}{B}\right]$. Hence, regardless of which is selected $\sigma < 1 - \frac{\lambda h_p}{B} = \sigma^p$ if $X = X_3$. ■

Adopting the taser leads to less resistance, but adds to the harm if resistance does occur. What is the net effect? The expected harm if P is used is $\sigma^p h_p = \left(1 - \frac{\lambda h_p}{B}\right) h_p$, while if T is adopted it is $\sigma^t h_t = \left(1 - \frac{\lambda h_t}{B}\right) h_t$. The latter is greater if

$$h_t + h_p < \frac{B}{\lambda}. \quad (6)$$

Thus, if the two technologies do not cause a significant amount of harm so that (6) holds, then adopting the new technology leads to a greater expected harm.

Result 4 Suppose $r_{gp} < 1 - \frac{\lambda h_g}{B} < r_{tp}$ and $r_{tp} < r_{gp}$. If $h_t + h_p < \frac{B}{\lambda}$, then the expected harm is greater if $X = X_3$ than if $X = X_2$. Otherwise it is less.

Proof. From the proof of Result 3 if $r_{gp} < 1 - \frac{\lambda h_g}{B} < r_{tp}$, then σ^p is the unique equilibrium outcome if $X = X_2$ and σ_{tp} , σ_{gt} , and σ_t are the equilibrium outcomes if $X = X_3$. The expected harm if $X = X_2$ is $\sigma_p h_p = \left(1 - \frac{\lambda h_p}{B}\right) h_p$, while if $r_{tp} < r_{gp}$ then σ_t is selected the expected harm if $X = X_3$ with σ_t is $\sigma_t h_t = \left(1 - \frac{\lambda h_t}{B}\right) h_t$. The former is less if (6) holds. ■

Thus, if the harm to using pepper spray is low, then adopting a taser results in more harm. Interestingly, if the harm to using a taser is low, then the adoption of a taser results in a greater expected harm. This is because if the harm is minimal, then the rate of resistance to arrest is still rather high and the new technology must be used with a significant probability. Additionally, if the proportion of the criminals that are irrational is high (low λ) and the number of criminals with a significant benefit to resisting arrest is great (high B), then the adoption of the less-violent technology increases the expected harm since the substitution to it from a mildly-violent technology is used on more criminals.

4 Discussion

What impact does the adoption of a less-violent technology have on the amount of violence? As an application of this question, a theoretical model is developed considering a criminal deciding whether to resist arrest and a law enforcement officer selecting which technology to use to suppress the criminal and make the arrest: a gun, pepper spray, or a taser (if available). It is shown that there exist environments where the rate of resistance to arrest increased if the taser is made available to the officer. This environment is characterized by the:

- (a) gain to attempting the arrest with a gun is significantly greater than pepper spray
- (b) gain to attempting the arrest with a gun is not significantly greater than the taser
- (c) liability to the enforcement official using a gun is not significantly greater than the liability using pepper spray
- (d) liability using the gun is sufficiently greater than if using a taser

In such an environment one would expect to see law enforcement officials begin to substitute a taser for a gun and, consequently, the rate of resistance to arrest increases. Thus, while a less-harmful technology is being used the rate of resistance is increasing so that more use of the technology results – there is a strategic offsetting behavior. A net increase in the expected harm to the criminal occurs if

- (e) both the gun and the taser result in a sufficient amount of potential harm if used
- (f) there is a small population of irrational criminals
- (g) there are few criminals with a strong motivation to resist arrest.

Therefore, if conditions (a) – (g) hold, then we get the perverse outcome of an increase in both resistance to arrest and expected harm if law enforcement are additionally equipped with tasers. If conditions (a) – (d) hold and (e) – (g) do not, then substitution from a gun to a taser results in less harm, even though additional resistance arises.

It is also shown that there exist environments where the rate of resistance de-

creased if the taser is adopted. These environments are characterized by the:

- (h) gain to attempting the arrest with a gun is not significantly greater than pepper spray
- (i) gain to attempting the arrest with a taser is sufficiently greater than pepper spray
- (j) liability to the enforcement official using a gun is significantly greater than the liability using pepper spray
- (k) liability using the taser is not much greater than if using pepper spray.

In such an environment one would expect to see an enforcement official substitute from the mildly-violent technology to tasers. Facing an elevated level of potential harm, fewer criminals are likely to resist arrest. This results in a net decrease in harm if:

- (l) both the taser and the pepper spray result in a significant potential harm if used
- (m) there is a small population of irrational criminals
- (n) there are few criminals with strong motivations to resist arrest.

Therefore, if conditions (h) – (n) hold, then we get the ideal outcome of a decrease in both resistances to arrest and expected harm if law enforcement are additionally equipped with tasers. If conditions (h) – (k) hold and (l) – (n) do not, then substitution from pepper spray to a taser results in more harm, even though resistance decreases. What arises as the important distinction between the environments is whether tasers are substituted for more-violent technologies or less-violent ones.

How might the analysis aid law enforcement policymakers? First, a critique of the current use of tasers by law enforcement is that there are not sufficient protocols for their use (Editorial 2008; White and Ready 2008). This rather straightforward, simple theoretical model can provide a beginning point to identifying the environments in which enforcement officials are to be equipped with the additional technology. Second, in the enforcement official's payoff is the liability she is exposed to using a particular technology. A reasonable component of the liability term is sanctions imposed such as unpaid suspensions, which is a variable policymakers could influence. The potential liability if using a taser affects the existence of both environments. Thus, it is possible

that an increase in this term reduces the additional resistance if a taser is substituted for a gun, (d), and a decrease in the term expands the environment where a taser is substituted for pepper spray, (k), decreasing resistance. Third, more appropriate use of the taser may lead to less harm. Suggestions such as restrictions against using a taser on the elderly, children, or pregnant women along with restrictions on the number of seconds a taser can be used or the multiple tasing by more than one enforcement official may lead to less harm if used (Amnesty International 2007; Editorial 2008; NIJ Special Report 2008). Amnesty International has called for a policy “to either cease using [t]asers and similar devices pending the results of thorough, independent studies, or limit their use to situations where officers would otherwise be justified in resorting to deadly force” (Amnesty International 2007). Better information and more accurate perceptions should lead law enforcement and policymakers to good use of tasers, but a moratorium is justified if the appropriate conditions are met. The environments identified here may help assess whether such calls are to be heeded.

The theoretical model is simplified. While the environment considered is a simultaneous-move one, the equilibria outcomes described continue to hold if the selections are made sequentially. Since the equilibria analyzed are pure strategies if the second-mover selects the derived action regardless of the initial selection, then each outcome studied is one in the sequential-move game; regardless of whether the officer or the criminal moves first. There would, though, be a number of other equilibria. Additionally, the payoff variables can capture any benefit and cost by the officer and criminal. For example, the liability term may not only be criminal and/or civil sanctions, but loss in psychological well being. The harm to the criminal include both physical harm and the disutility of apprehension. Also, one may view the payoffs as expected values where uncertainty of arrest, harm, etc. is considered.

The theoretical model has a number of limitations, though, left for future consideration. First, to discuss the impact of the new technology intermediate values of

r_{gp} were not considered. For such values a coordination game arises with multiple equilibria. With multiple equilibria it is difficult to predict which outcome arises and, therefore, it is not possible to compare outcomes under different sets of available technologies. Second, the results point to only the *possibility* of elevated resistance and expected harm or reduced resistance/harm. An empirical investigation identifying the *actual* environment in which law enforcement operate in is needed. Third, while allowances were made for the possibility of irrationality on the part of the criminal the framework considers an official who makes a rational choice. Such a choice may at times prove difficult and an extension allowing for the possibility of less-than-fully-rational choices may be valuable. Additionally, the theoretical model is rather simplistic and additional considerations could be incorporated to check the robustness of the results. Officers and criminals may have actions available during the apprehension to limit the harm or affect the likelihood of a successful arrest. Also, the model does not directly address the potential for officer and third-party injury. Similarly, the analysis does not consideration the possibility of the adoption of the new technology on the decision to commit a crime (deterrence).

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