A Theoretical Model of the Public-Private Provision of Security Goods Against Crime

by

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Abstract

This thesis builds a theoretical model to analyze the provision of public security and private security against crime. This thesis models a government that values both potential victims and legitimate production (non-criminal) of criminals. I find that if a government cares about legitimate production of criminals and protecting potential victims, it will invest more in public security in comparison to a government that only cares about protecting potential victims. I also find that if a government values legitimate production of criminals as well as the welfare of potential victims, and if legitimate production for a criminal is small, the government will increase public security investment in equilibrium as legitimate production increases for a small range of legitimate production. However, eventually after a certain value of legitimate production, the government will start to decrease investment in public security in equilibrium. In contrast, a government that only cares about protecting potential victims will always decrease its public security investment as legitimate production increases.

Keywords: Economics of Crime, Economics of Security, Public-Private Provision.

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I. Introduction

In this thesis, I develop a game-theoretical model to examine the provision of security against crime when security is both publicly and privately supplied to combat crime. I develop a model in which the government cares about criminals to the extent they produce legitimately. It is self-evident that ensuring the security of citizens is one of the most important roles of government and understanding how that interacts with private individuals protecting themselves would be useful in designing public policy to combat crime. However, I aim to understand how the government would behave if protecting people was not the only objective of the government. In this case, the government also attempts to maximize legitimate production of criminals. Some of the literature in the economics of crime either assumes the government does not care about criminals at all, or that governments value criminal activity.

I analyze the optimal provision of security goods when the effect of private security is solely to protect an individual from criminal harm and the effect of public security is solely to increase the probability that criminals are caught after crimes have been committed. The model is a two-stage sequential game with three groups of players: criminals who choose who choose how to allocate effort between crime and legitimate production, potential victims who choose how much of their vulnerable wealth to protect, and a government that chooses how much to tax potential victims and how much to invest in public security. Potential criminals and potential victims are homogenous. In this model, the government does not have a purely utilitarian objective function, which would maximize the utility of both criminal and victim, nor is it solely concerned with potential victims (does not care about criminals at all). The government is concerned with maximizing the welfare of the potential victims and legitimate production of potential criminals.

One fundamental difference between analyzing security provision in response to crime as opposed to other threats such as natural disasters or disease is that criminals are considered part of society and so their welfare should, arguably, be considered when analyzing total social welfare. Also, certain policies useful in addressing non-human threats, such as a disease epidemic, may not be considered an ethical response to criminals. For example, a disease can be eradicated through a program of vaccinations without any significant moral dilemma, while a policy calling for the killing of criminals may be considered morally unacceptable. Most developed countries have laws preventing cruel and unusual punishment. These limit the ability of governments to deter crime through the threat of ever more severe punishments. I argue that it may also be unpopular for a government to encourage crime if criminals value the benefit of crime more than the cost to the victim. Another fundamental difference between crime and other threats such as natural disasters is that criminals respond to incentives. Criminals are also capable of doing legitimate activities that would contribute to their welfare and society's welfare. For example, criminals could be compelled to choose to work in a legitimate job rather than stealing. Hence, I propose that the more reasonable assumption for a government objective function is to care about the welfare of criminals if their wealth comes from legitimate (non-criminal) sources.

I find that if a government cares about legitimate production of criminals and protecting potential victims, it will invest more in public security in comparison to a government that only cares about protecting potential victims. I also find that if a government cares about legitimate production of criminals and protecting potential victims, if legitimate production for a criminal is small, the government will increase public security investment in equilibrium as legitimate production increases for a small range of legitimate production. As legitimate production increases in equilibrium, private security investment and criminal effort decreases. I find that when punishment levels increase in equilibrium, governments invest more into public security, criminals decrease their effort into crime, and potential victims invest less in private security. Also, I find that as payoffs from crime increase in equilibrium, that private security investment also increases. However, as payoffs from crime increase, both public security investment and criminal effort decrease.

II. Literature Review

In the economics of crime literature, criminals can be deterred in three major ways: better opportunities, harsher punishments and an increase in the probability of being caught (Chalfin & McCrary, 2017), and the results of my model, regarding the behaviour of criminals, are consistent with the literature.

McDonald (1987) claims that the structure of the social welfare function is the crucial assumption of most of the literature in the economics of crime. Becker (1968) is considered the seminal paper that uses welfare analysis in the context of crime, but many criticisms have followed this paper because of how the social welfare function was structured (McDonald, 1987). Becker (1968) uses a purely utilitarian approach in which crimes, like theft, are a pure wealth transfer between victims and criminals. In some papers, criminals' utility is weighted differently than victims' utility (McDonald 1987). In some papers, criminals' utility is not considered at all in the government's objective function (Hickey, Mongrain and Roberts, 2015). As a response to Becker (1968), McDonald (1987) creates a weighted social welfare function that results in changing optimal levels of security and punishment depending on how criminals' and victims' utilities are weighted. An increase in the weight of victims results in an increase in the optimal provision of security and punishment levels. An increase in the weight of the criminals' utility results in a decrease in the optimal provision of security as well as a decrease in punishment severity. The major difference in my model is that I attempt to analyze a situation in which the criminals can choose between crime and legitimate production as a fraction of their time with a government concerned with maximizing the welfare of potential victims and the legitimate production of criminals.

A working paper by Hickey, Mongrain and Roberts (2015) creates a theoretical model in which the government is concerned only with potential victims and does not consider the utility of criminals at all. Criminals in Hickey, Mongrain and Roberts' (2015) model only have an option to commit a crime or not, and no alternative option is available to them. They allow private security to be both a complement and a substitute to public security. Hickey, Mongrain and Roberts (2015) find that the government oversupplies public security if public and private security are complements, in contrast to a situation in which the government can choose public and private security investment. The government undersupplies public security if public and private security are substitutes, in contrast to a situation in which the government can choose public and private security investment. They also find that even if private and public security are complements, they can still be net substitutes because as public security increases, the effectiveness of a unit of private security increases, and hence potential victims may substitute out. My model differs from this approach by incorporating the idea that private security and public security do different things. In my model private security can decrease the negative impact of being a victim of crime and make the payoffs smaller for criminals. Public security increases the probability that a criminal is caught. Also, in my model, criminals are included in the government's objective function.

Helsley and Strange (2005) creates a two-stage theoretical game. The government and potential victims make simultaneous choices on how much security to invest in, then criminals make a choice of who to target and the severity of crime. In this model, the government only chooses how much to invest in public security to maximize the welfare of all the potential victims. The criminals' utility is not considered in the government's objective function. They find that the mixing of private security and public security is inefficient. My model considers a two-stage game as well, but the government decides the tax rate, and how much to invest in public security. Then, in my model, the criminals and potential victims make their choices simultaneously. This is a more reasonable timing since government spending and taxation is public information, whereas potential victims may not be able ascertain the decisions of criminals, and criminals may not be able to ascertain how much private security a potential victim has.

In conclusion, I attempt to add to the literature by building a theoretical model in which private and public security interact to prevent criminal activity, but in a model in which the government cares about the legitimate production of criminals.

III. The Model

3.1 Basic set-up

There are three groups of agents in this model: potential victims, potential criminals and a government. There are N potential victims and C potential criminals: each group is homogenous. I assume that criminals cannot be victims.

The theoretical game is played sequentially in two stages. In the first stage, the government chooses how much to invest in public security and sets a tax rate on the wealth of potential victims to cover the cost, keeping the government budget in balance. In the second stage, potential criminals choose how much effort to invest in crime, and potential victims choose their investment in private security. I explain the differences between public and private security below. In the second stage, potential criminals and potential victims make their choices simultaneously. For simplicity, I will focus on theft.

Investment in private security protects an individual potential victim by shielding a percentage of their at-risk wealth from loss if a crime occurs. At the same time, as private security investment increases, the probability that a potential victim will indeed be a victim is lowered. Since the agents are homogenous and invest in the same amount of private security, the diversion of criminals to another potential victim is not modelled. The effect of public security in this model is that it increases the probability of capture and deters crime through this mechanism. When a criminal is captured, they are punished depending on how much effort they expended in the commission of the crime.

3.2 Criminals

A potential criminal chooses the amount of effort $x \in [0,1]$ to dedicate to crime and dedicates the rest of their effort *(1-x)* to legitimate production. A criminal receives a punishment Jx^2 when caught. J is the maximum punishment a criminal will receive. The severity of the punishment increases at the margin with the effort a criminal spends on crime. As a criminal dedicates more effort to crime, that is x is larger, the criminal will receive a larger punishment. The quadratic form is use for two reasons: technical convenience and real-world examples. In Canada, theft has increasing marginal punishments. In Canada, theft under $5000 results in a maximum punishment of two years in prison, and if the theft exceeds $5000, the maximum punishment increases to ten years in prison (Legislative Services Branch, 2019).

I assume that maximum punishments are a fixed parameter, and hence the government cannot change it. I make this assumption because J is meant to represent the maximum punishment the government is legally allowed to give. For example, in Canada, the maximum punishment the government can give a convicted criminal is life in prison without eligibility for parole. Torturing criminals is usually not an option, since many developed countries have constitutional protections against cruel punishments; in the same spirit, fines can not be extremely large. In this model, J only represents fines and not prison time. Another reason why fines are limited is because of bankruptcy constraints. That is, you can only take so much wealth for a person until they have no more to give, and hence would limit the threat of fines. I am assuming that criminals pay for this fine from a stock of unmodelled wealth. For simplicity, I assume this wealth will not be taxed, so implicitly perfect tax evasion is another incentive to crime.

Criminals dedicate the rest of their effort $1-x$ to legitimate production. The maximum legitimate production a criminal can create is H. Hence, the total legitimate production a criminal produces is $(1-x)H$.

The maximum payoff of crime is P. As a criminal spends more effort on crime, the payoff is greater, which is represented by the term xP. From the prospective of the potential victim, P is the amount of at-risk wealth, and hence they can protect a percentage of it, $\sigma \in [0,1]$, through private security. In this case, the final payoffs of crime for criminals is $(1-\sigma)xP$.

There is a probability d that a criminal gets caught. d increases as public security Θ increases. The functional form for d is

$$d(\Theta) = 1 - \frac{1}{\frac{\Theta}{N + C} + 1} \quad (1)$$

The effectiveness of public security is scaled by the number of potential victims and potential criminals. So, in this model, public security is a common good that loses its overall effectiveness when the population is larger. For simplicity, I assume that only public security affects the probability of catching a criminal. I assume that only private security affects the amount of wealth lost when a potential victim becomes a victim. This is motivated by a real-world example that hiring an additional police officer would most likely increase the probability of capture more than hiring an additional security guard. For an individual, hiring a security guard would most likely be more effective in protecting the individual's wealth than having an additional police officer. Since police officers are usually called when crimes have already happened, and a security guard would already be at the scene of the crime to protect whatever they are meant to protect, the security guard would not be as concerned with catching the criminal as protecting what is at risk.

If a criminal is caught, they must return the wealth stolen and compensate the victim to the best of their ability. In this model, a criminal will return $\alpha(1-\sigma)xP,$ where α is the degree of recoverability of wealth. $\alpha \in [0,1]$. Implicitly, α also includes unmodelled wealth the criminal has, net of fines, that they can use to further compensate the victim. If $\alpha = 1$, this would model a pure wealth transfer back to the victims. A real-world example of this would be stolen financial assets that are returned in full. Since the criminal did not have a chance to consume their payoff, their net payoff after being caught is zero. If $\alpha = 0$, this would be akin to stealing money and immediately using it for consumption, and further, the criminal has no additional wealth. Even if the criminal is caught for the crime, there would be no way for the criminal to return that payoff to restore the victim to their original level of wealth. In this situation, the criminal has already received their utility from the crime and that can not be taken away.

Functionally, the criminal's objective function is:

$$\max_{x} U = d[(1-\sigma)xP - \alpha(1-\sigma)xP + (1-x)H - Jx^2] + (1-d)[(1-\sigma)xP + (1-x)H] \quad (2)$$

The first-order condition is:

$$\frac{dU}{dx} = 0 = -\frac{P\Theta\alpha\sigma + CP\sigma + 2J\Theta x + NP\sigma - P\Theta\alpha + P\Theta\sigma + CH - CP + HN + H\Theta - NP - P\Theta}{\Theta + N + C} \quad (3)$$

3.3 Victims

A potential victim is endowed with wealth *W*. An amount *P* of this wealth is at risk of being stolen. The victim chooses the amount of private security σ to maximize their wealth (or minimize wealth lost). $\sigma \in (0,1)$. σ is a percentage of at-risk wealth that a potential victim chooses to protect. P_σ is the price of protecting all the at-risk wealth. A potential victim is endowed with wealth *W*. A potential victim is taxed at a tax-rate of *t*. Hence, the potential victims has an after-tax wealth of *(1-t)W*. There is a probability δ that a potential victim will be a victim of crime. Functionally:

$$\delta = \frac{xC}{\sigma N} \quad (4)$$

There are three states for potential victims. 1) They are victims, and the criminal is caught. 2) They are victims, and the criminal is not caught. 3) They are not victims. If a potential victim does become a victim and the criminal is caught, their final wealth will be

$$(1-t)W - (1-\sigma)xP + \alpha(1 - \sigma)\mathrm{xP} - P_\sigma \sigma \ (5)$$

If a victim does become a victim of crime and the government does not catch the criminal, a victim's final wealth will be

$$(1-t)W - (1-\sigma)xP - P_\sigma \sigma \ (6)$$

The difference in payoffs between the two states is $\alpha(1 - \sigma)\mathrm{xP}$, which, as in the criminal's case, represents the wealth that can be transferred back to victim if the criminal is caught.

If a potential victim does not become a victim of crime, their final wealth will be

$$(1-t)W - P_\sigma \sigma \ (7)$$

So, a potential victim will lose only the wealth they invested in private security and the amount of taxes they pay.

The potential victim's objective function is:

$$\max_\sigma V = \delta d[(1-t)W - (1-\sigma)xP + \alpha(1-\sigma)\mathrm{xP} - P_\sigma \sigma] + \delta(1-d)[(1-t)W - (1-\sigma)xP - t - P_\sigma \sigma] + (1-\delta)[(1-t)W - P_\sigma \sigma] \ (8)$$

Simplified:

$$\max_\sigma V = (1-t)W - P_\sigma \sigma + \frac{xC}{\sigma N} d[\,(\alpha-1)(1-\sigma)\mathrm{xP}] + \frac{xC}{\sigma N}(1-d)[-(1-\sigma)xP] \ (9)$$

The first-order condition is:

$$\frac{dV}{d\sigma} = 0 = \frac{CP\alpha\Theta x^2 + C^2x^2P + CNPx^2 - CN\sigma^2P_\sigma + CP\Theta x^2 - N^2\sigma^2P_\sigma - N\Theta\sigma^2P_\sigma}{\sigma^2N(\Theta + N + C)} \quad (10)$$

Government

The government invests in public security Θ and acquires *t* percent of wealth from each potential victim to finance public security investment. The government runs a balanced budget. P_Θ is the price of one unit of public security. Public security is squared in the constraint function to represent the fact that public security diminishes in effectiveness as public security increases. The government will also earn $dCJx^2$ from the fines it has imposed on criminals but will need to spend P_j to finance the justice system. I assume that P_j is a fixed cost that does not change with *J*. Intuitively, the cost of fining someone $100, in comparison to $200, would most likely not require more resources for policing and the processing of fines.

The government draws utility from the wealth of potential victims and the legitimate production of criminals. The government attempts to maximize its utility.

The government's objective function is:

$$\max_{\Theta,t} G = NV(\Theta, t(\Theta)) + \mathrm{C}(1 - \mathrm{x}(\Theta))(H) \quad (11)$$

$$subject\ to\ NtW +\ x^2dCJ\ \geq P_j\ +\ P_\Theta\Theta^2 \quad (12)$$

Solving for *t* in the constraint function and substituting it in the objective function, the unconstrained first order condition is for public security investment is:

$$\frac{dG}{d\Theta} = 0 = \frac{1}{\sigma(\Theta + N + C)^2 W}(C^2PW\alpha\sigma x^2 + CNPW\alpha\sigma x^2 - C^2PW\alpha x^2 - CPNW\alpha x^2$$
$$+ C^2JW\sigma x^2 + CJNW\sigma x^2 + C^2J\sigma x^2 - 2C^2\Theta W\sigma P_\Theta + CJN\sigma x^2$$
$$- 4CN\Theta W\sigma P_\Theta - 4C\Theta^2 W\sigma P_\Theta - 2N^2\Theta W\sigma P_\Theta - 4N\Theta^2 W\sigma P_\Theta - 2\Theta^3 W\sigma P_\Theta$$
$$- 2C^2\Theta\sigma P_\Theta - 4CN\Theta\sigma P_\Theta - 4C\Theta^2\sigma P_\Theta - 2N^2\Theta\sigma P_\Theta - 4N\Theta^2\sigma P_\Theta$$
$$- 2\Theta^3\sigma P_\Theta \quad (13)$$

IV Comparative Statics

Since a closed form analytical solution is not possible for the theoretical game, a numerical solution with arbitrarily set parameters (see Table 1 in the Appendix) will be used to do comparative statics. The parameters of interest are the magnitude of the fine, the maximum payoffs, and the maximum amount of legitimate production a criminal can produce. These are parameters of interest because in the economics of crime, harsher punishments, better non-criminal opportunities, and higher payoffs of crime are the incentives criminals respond to the most (Chalfin & McCrary, 2017).

I graph the optimal equilibrium values of public security, private security and criminal effort as a function of the parameters of interest. All the graphs represent the general equilibrium values of the choice variables and not the best response functions.

4.1 Fines

Figure 1 shows a graph of the optimal public security investment as maximum punishment changes.

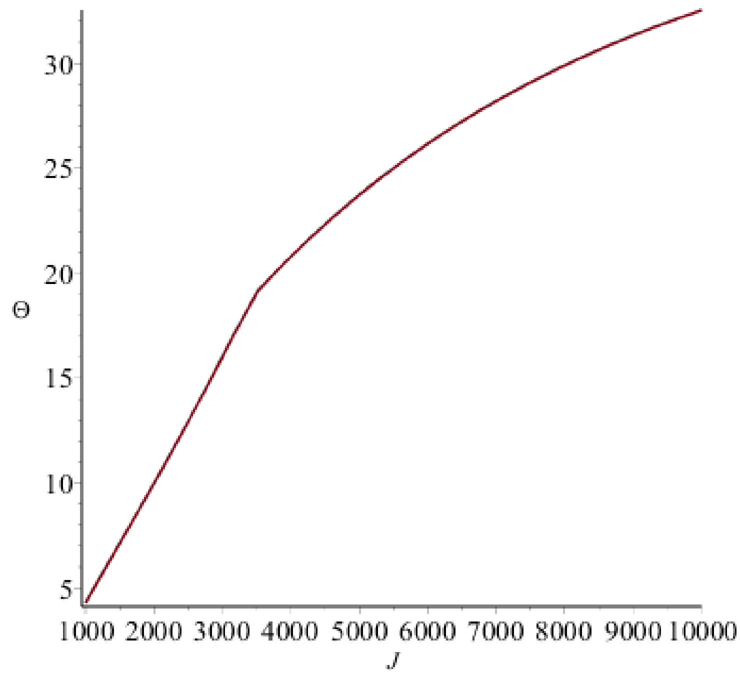

Figure 1: A graph of the optimal public security investment as a function of the maximum fine

As punishment levels increase in equilibrium, the government invests more and more in public security. There are two ways this shift can happen. The effectiveness of deterring criminals from committing crimes can come from the threat of punishment. The expected magnitude of the punishment can come from the combination of the probability of capture and the magnitude of the fine. So, as the magnitude of the fine increases, the effectiveness of one unit of public security in deterring crime also increases. The second mechanism by which public security increases is that the government generates more revenue when criminals are caught, and hence has more income to spend on public security. A potential extension to this thesis would be to analyze the individual effects of these two mechanisms.

Figure 2 shows a graph of the optimal criminal effort as maximum punishment changes. As punishment levels increase in equilibrium, criminals dedicate less time to crime.

Figure 3 shows a graph of the optimal levels of private security investments, as a function of changing the maximum fine. It appears that since there is less criminal effort and higher public security, potential victims will invest less in private security.

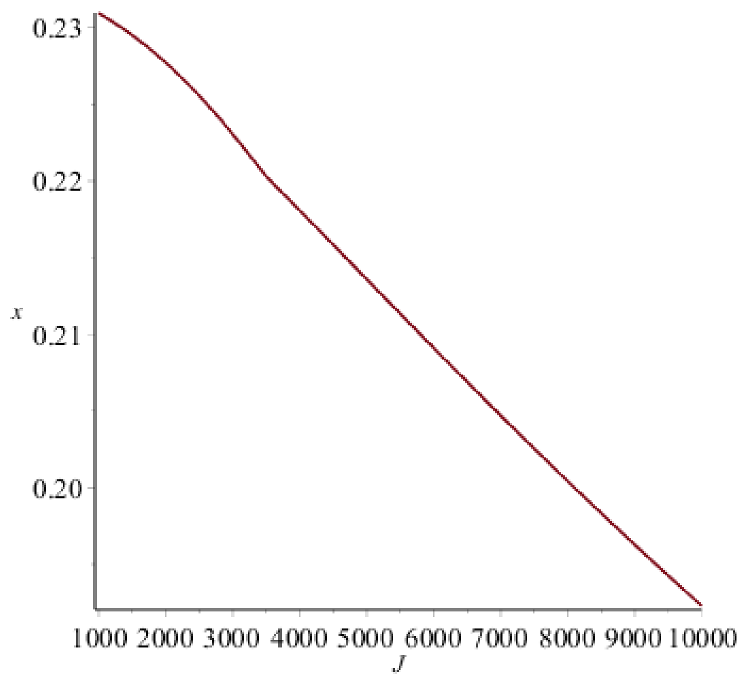

Figure 2: A graph of the optimal criminal effort as a function of the maximum fine.

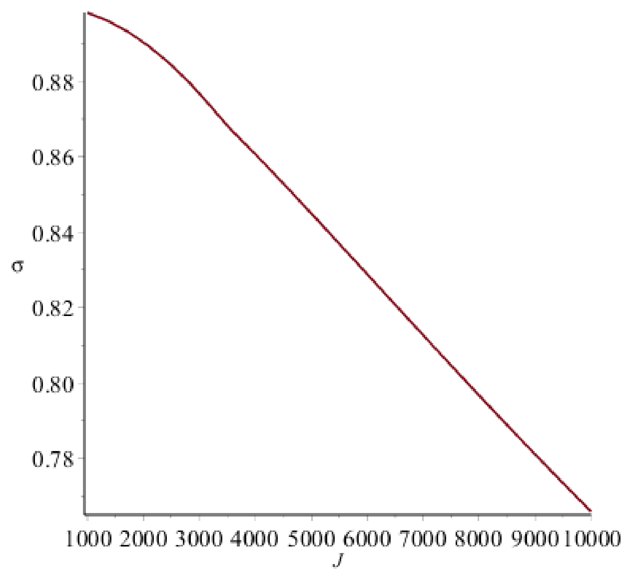

Figure 3: A graph of the optimal private security investment as a function of the maximum fine.

4.2 Legitimate Production

Figure 4 shows a graph of optimal public security as function of changing maximum legitimate production. It appears that in a neighbourhood of smaller values of legitimate production, the government increases public security to compel potential criminals to switch away from crime and into legitimate production, but as legitimate production increases beyond the smaller values of legitimate production, criminals substitute away from crime and engage in legitimate production more, hence less public security is required. Figure 5 graphs optimal criminal effort as a function of changing legitimate production. In appears that as legitimate production increases, criminals move away from crime and dedicate more effort into legitimate production. In Figure 6, as legitimate production increases and criminal effort decreases, potential victims invest less and less into private security.

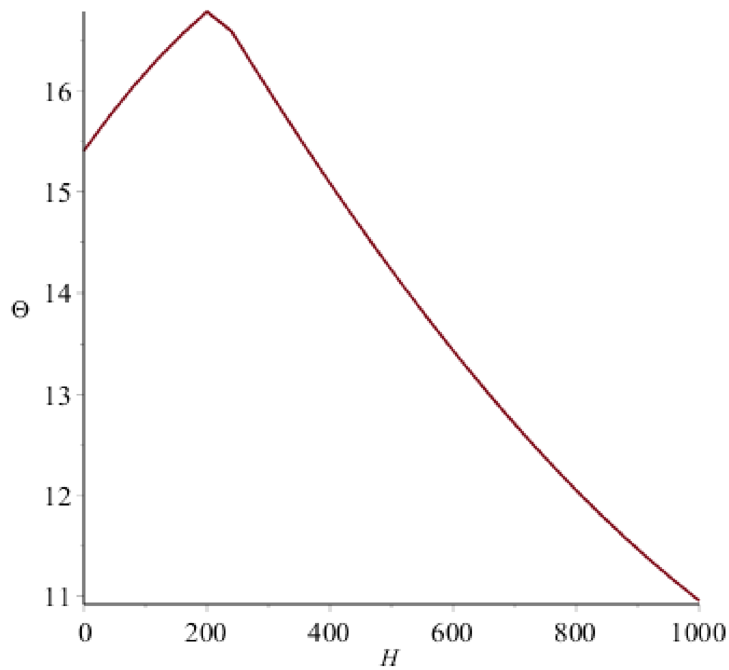

Figure 4: A graph of the optimal public security investment as a function of the maximum legitimate production

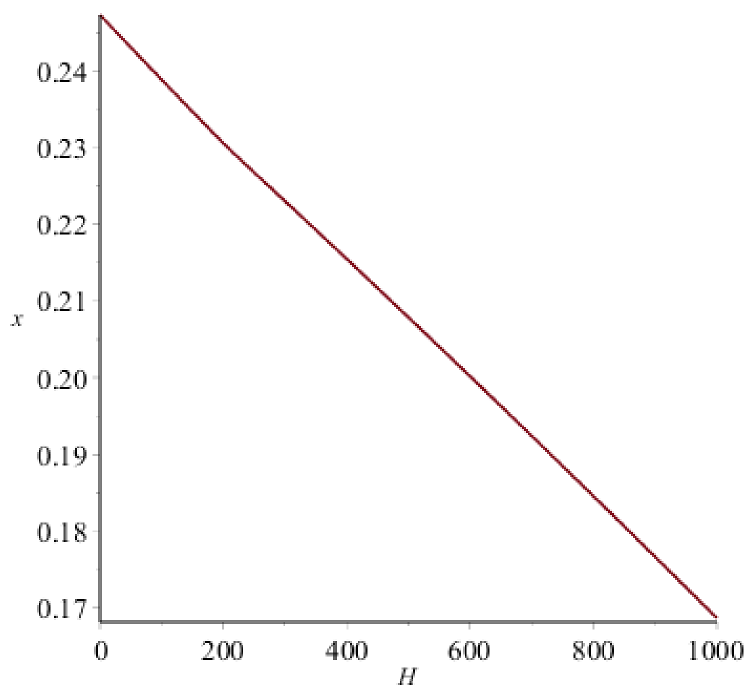

Figure 5: A graph of the optimal criminal effort as a function of the maximum legitimate production

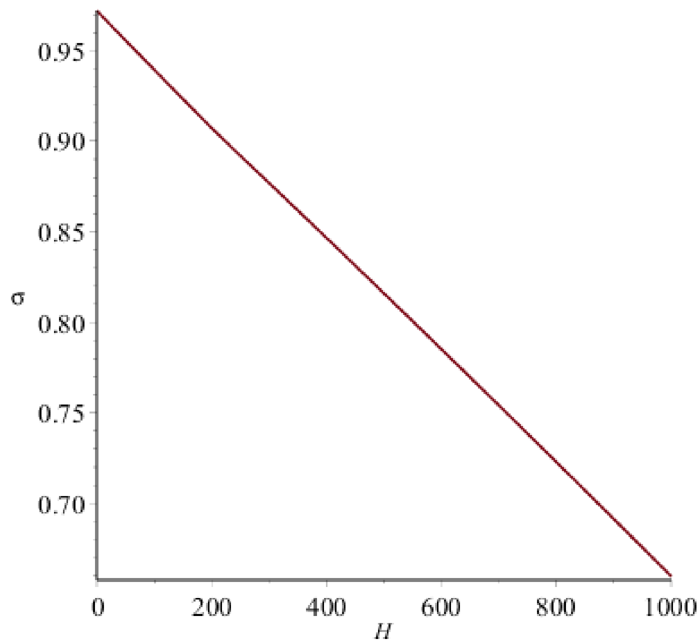

Figure 6: A graph of the optimal private security investment as a function of the maximum legitimate production

4.3 Payoffs/At-risk Wealth

According to Figure 9, as at-risk wealth increases, potential victims invest more into private security, so in equilibrium, potential criminals invest less into crime according to Figure 8. For potential criminals, the maximum payoffs of crime, net of private security, is $(1-\sigma)P$. So as private security increases, the potential payoffs for criminals decrease. According to Figure 7, in equilibrium, the government invests less in public security.

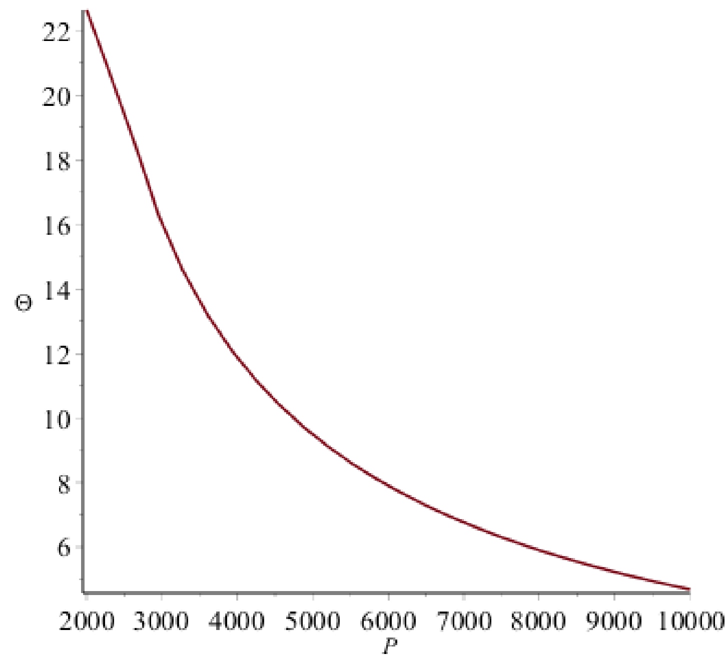

Figure 7: A graph of the optimal public security as a function of maximum payoffs

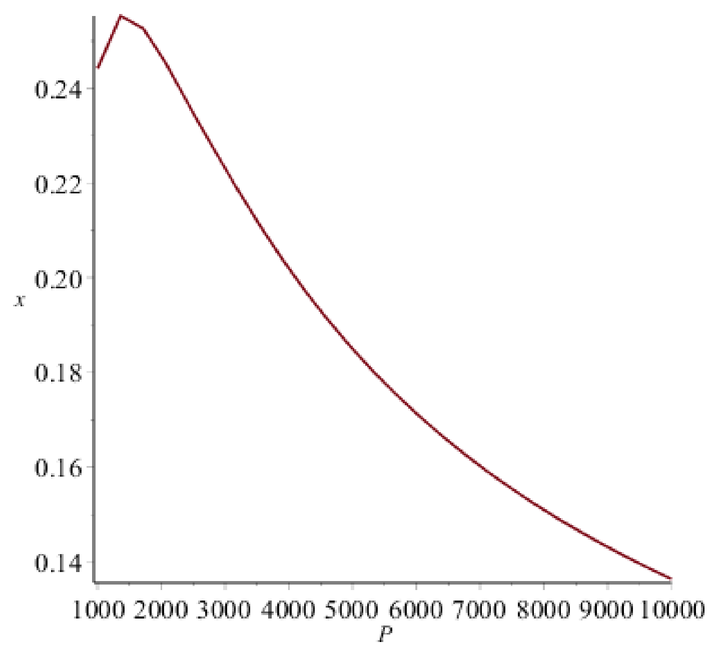

Figure 8: A graph of the optimal criminal effort as a function of maximum payoffs

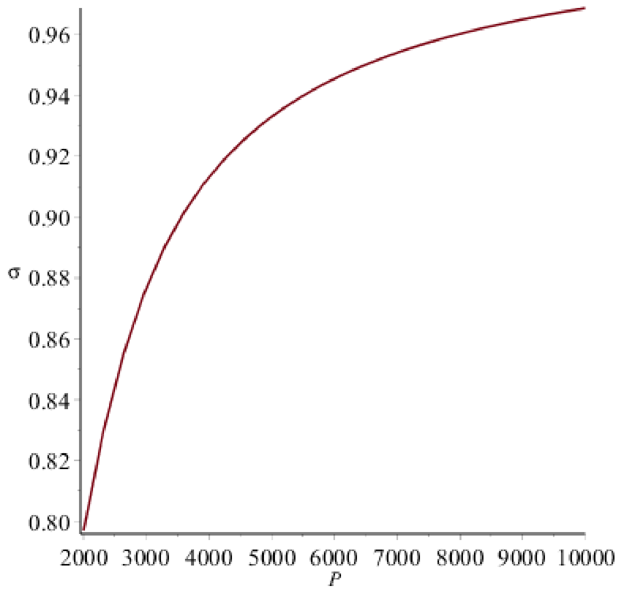

Figure 9: A graph of the optimal criminal effort as a function

4.4 Comparing Government Objective Functions

Figure 10 illustrates two different government objective functions. *G* represents the government function in which the government is attempting to maximize the wealth of potential victims and the legitimate production of criminals. *G1* represents a government function in which the government only cares about the wealth of potential victims.

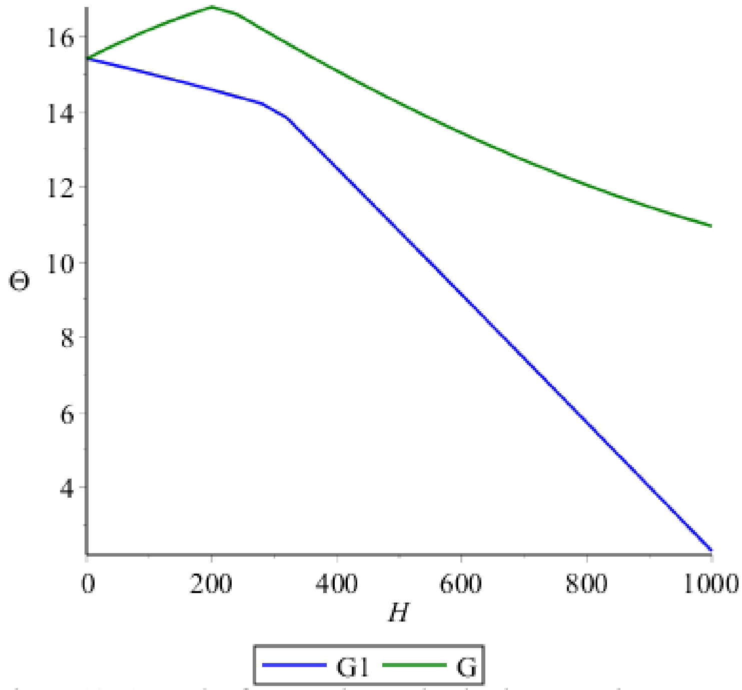

Figure 10: A graph of comparing optimal private secuity between G and G1.

For a government that is only concerned with maximizing the wealth of potential victims (*G1*), optimal private security investment is less for any level of home production, and the rate of decrease is much greater in comparison to a government that is concerned with legitimate production of criminals. Also, for a government that is only concerned with maximizing wealth of potential victims, it will always decrease public security investment as legitimate production increases. In contrast, when legitimate production is small, a government that also values legitimate production of criminals will increase public security as legitimate production increases.

V Conclusion

In this thesis, I model how a government would behave if it values protecting not only potential victims, but also criminals who legitimately produce. This model provides a simple framework to analyze the provision of public and private security against crime, but many extensions may be made to this model. One extension could be analyzing a three-stage sequential game, in which the government moves first, followed by the potential victim and finally the criminal. This setup would indicate that private security is observable to the criminal.

Another extension would be to use jail time instead of fines. In this setup, if a criminal is not caught, a criminal will dedicate their non-criminal effort to legitimate production, but if a criminal is caught, then they would dedicate time to legitimate production and jail time. In this setup, jail would be costly to the government in two ways. First, prisons are costly to run. Second, putting a criminal into prison incapacitates them from committing more crimes, but the government will also lose the potential legitimate production the criminal would have done if they had not gone to jail. Another extension could explicitly assume complementarity of public security and private security. An example of this can be found in Hickey, Mongrain & Roberts, J (2015), which is a home alarm system that alerts the police if there is a break-in. In this scenario, the police would not be effective if the home system failed and did not alert them. Similarly, if the police are not very effective, then the effectiveness of the home alarm system diminishes. Another possible extension would be the government having the option to invest in enhancing legitimate production of criminals.

Finally, another extension to the model would be adding externalities. For example, if potential victims are heterogenous, if a group of potential victims invests in private security, they could potentially divert criminals to those who do not have private security. Similarly, potential victims could also invest in private security from which others can benefit without cost, creating a positive externality.

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Appendix

Parameters	**Numerical Value**
Number of Potential Victims (N)	200
Number of Criminals (C)	50
Wealth (W)	10000
Maximum Payoffs (P)	3000
Degree of replaceability of wealth (α)	0.5
Price of Public Security (P_{Θ})	1
Price of Private Security (P_{σ})	50
Price of the Justice System (P_j)	60000
Maximum Punishment (J)	3000
Maximum Legitimate Production (H)	300

Table 1: A table of the arbitrarily set numerical values for the parameters used for comparative statics