The Interaction of Communities, Religion, Governments, and Corruption in the Enforcement of Contracts and Social Norms*

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Abstract

Are informal communities and formal government policing substitutes or complements in enforcing norms of reciprocation and exchange? How do religion and corruption affect that interaction? We introduce a model in which people exchange informally within their community as well as externally on a market in which transactions are policed. We show that informal community enforcement and formal policing are complements: the news that someone was caught by the police can lead to community ostracism, bolstering incentives. Although community transactions offer less direct benefits, their presence lowers overall costs of enforcement and it may be welfare-maximizing for a society to rely on both community and formal exchange. We explain why the optimal mix of community and formal markets is discontinuous in underlying parameters. We also show that religion can enhance the complementarity between community and formal policing, while corruption undermines it.

Keywords: Religion, Community, Government, Police, Contracts, Reputation, Enforcement, Laws, Trust, Corruption, Norms

JEL Classification Numbers: C72, C73, D23, D73, H11, K12, O17, P48, P51, Z12

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"The key to successful economic exchanges here is not necessarily an impartial and efficient third-party enforcing agency, but the existence of a level of trust or other self-enforcing institutions within relevant networks of commerce, credit, wage-labor, and other contractual relations that support free market activities. In other words, the state is neither necessary nor sufficient. The simple model in which it is only the state and threat of its justice and police systems that makes people behave cooperatively seems a poor description of any known situation."

Joel Mokyr (2008), page 71

1 Introduction

The quote from Mokyr above makes clear the importance of incentives beyond the fear of the police in supporting economic exchange. Despite the mountains of evidence that reputations matter, we still know little about how informal social relationships *interact with* formal institutions in the enforcement of norms and contracts. Does the presence of one form of enforcement enhance the effectiveness of the other?

In this paper, we provide both empirical and theoretical analyses of how informal communities *complement* formal institutions to enforce basic exchanges in a society. We consider the simplest form of production, where people have tasks to complete in order to survive: producing food, shelter, clothing, caring for children, etc. They can either perform all tasks themselves, or informally share and exchange them with other members of their community, or perform some and exchange for others via markets in which contracts are enforced by a government and police. We consider mixtures in which some tasks are informally exchanged within a community and others are conducted via a market.

We treat government and policing as providing a "formal enforcement" of exchanges that occur through markets; and the pressures (e.g., threats of ostracism or other punishments) that come from communities as providing "informal enforcement" of exchanges that occur outside of the market. We also explore the impact of the supernatural beliefs that accompany some religions (e.g., any anticipated punishments and/or guilt that result from committing a sin) in terms of providing enforcement in both regimes: providing incentives to be honest in both market and non-market interactions. We explore the following questions. Are these various forms of enforcement complements or substitutes, or more specifically, under what circumstances are they complements? Why and when do we see co-existence of various forms of enforcement? How does corruption affect the functioning of both the formal enforcement as well as informal community enforcement, and the complementarity between the two?

We begin the paper with some cross-country correlations of overall production (log GDP) with the strength of community, religion, and the formal enforcement of laws. Although such correlations cannot be taken to be causal, they provide a backdrop and some basic guidance of facts with which a reasonable model should be consistent. As one should expect, the basic correlations are consistent with findings in some of the previous literature: GDP is negatively correlated with the amount of religious activity in a country, positively correlated the formal enforcement of laws, and positively correlated with a measure of how much one believes they can count on other members of one's community for help.[1] The more novel relationship that we note is an interaction effect: GDP is positively correlated with the product of community and rule of law. Thus, GDP is significantly more positively correlated with rule of law the greater the perceived strength of community. In other words, community and policing are complements in predicting productive outcomes.

Our main contribution is a new theory. We introduce a simple model that allows us to investigate the relationship between community and policing. In the model, the various tasks that a household has to undertake can be done by themselves, by others in their community, or by others in the general economy (through trade in markets). The benefit of exchanging with others in the community or general economy comes from specialization: an individual specializes in tasks in which s/he has a comparative advantage and then there is trade. The driving assumption is that the larger the pool over which there is exchange, the greater the benefits from trade and lower the overall costs of providing tasks. That is, production by autarky is more time-consuming than production within the community, which is more time-consuming than production by the most efficient means in the whole economy.

An equilibrium in this setting is then a specification of which tasks are exchanged in the community and which are exchanged in the overall economy. Community enforcement is informal and comes from the threat of ostracizing someone who has not delivered on the tasks that they were supposed to perform for others in the community. The future loss of interaction with others in the community thus forces the individual into autarky on those tasks that are normally done within the community. Enforcement of exchanges in the overall economy is done by a police force. People who do not perform are caught with some probability, which depends on the amount spent on the police force. Criminals are fined and their names are made public.

Instances of making criminals known to their communities are abundant in history. During the inquisition in Spain and Portugal, the auto-da-fé was a public parading of accused people (most of whom were not executed). In ancient China, among "the five punishments", mo, also known as qing, was the punishment where the offender would be tattooed on the face or forehead with indelible ink. The quote from Mokyr (2008) above refers to the importance of sustaining economic exchanges via reputations. As Mokyr states (pages 79-80): "In Britain during the Industrial Revolution, the social norms of what was perceived to be a

[1]Scheve and Stasavage (2006) finds evidence for religion as substitute for state in terms of providing social insurance. Campante and Yanagizawa-Drott (2015) estimates a negative effect of the strictness of a religious practice (Ramadan) on economic growth. For more general background on the economics of religion, see Iannaccone (1998); McCleary and Barro (2006); Iyer (2016) and the papers cited therein.

gentlemanly culture with an emphasis on honesty and meeting one's obligations, supported cooperative equilibria that allowed commercial and credit transactions to be consummated and partnerships to survive without overly concern about possible defections and other forms of opportunistic behavior. Gentlemen (or those who aspired to become gentlemen) moved in similar circles and faced one another in a variety of linked contexts. [...] The prevalence of a social convention that defined "gentlemanly" or "polite" behavior and penalized serious deviations from it through irreparable damage to one's reputation, supplemented formal (legal) relations with a moral code that enabled an effective mode of transacting without relying on the State except in extremis." In modern settings, there are public databases on malpractice suits in medicine and law, as well as lists of ex-convicts for various crimes, and publication of police logs of crimes by local newspapers and web sites. There are also many web sites that provide opportunities for people to report on transactions. These are all methods of making an individual's transgressions known to his or her community so that they can react and limit contact with the individual.

On a basic level, in our model there is substitution between exchanging tasks within one's own community and exchanging them more widely on the open market: tasks that are done in the general economy are no longer done within the community, and vice versa. However, we show that there is also an important *complementarity* between the two forms of exchange when some tasks are done on one and other tasks are done on the other. When people are caught by the police and their names becomes public, people within their communities may notice and can also choose to ostracize them. For instance, someone caught embezzling and cheating on a contract can lose his or her reputation and risks being ostracized by his neighbors. As a result, the punishment from getting caught by the police is more than the fine itself, and also includes the loss of the (future) value of community interaction. Policing becomes more effective as the use of community increases.

With this basic model in hand, we explore the welfare-maximizing equilibrium combination of community and police force. Although exchange within a small community is more costly in terms of having less efficient production; when combined with a formal market and policing it provides greater incentives at a lower cost of enforcement than a system that involves only policing or only community. As we show in detail, a split of doing some tasks within community and others on an open market can be optimal for a (wide) range of costs of policing.

The model provides several novel comparative statics - most notably in terms of the the cost of policing. When governments are very effective and policing is cheap, then no community exchange is needed and doing everything on the market is the efficient equilibrium. However, once policing becomes moderately expensive, then there is reliance on a combination of policing together with community interaction and enforcement. *There is an important* *discontinuity here*: the amount of community that must appear in any equilibrium is either zero or bounded away from zero. Having a small amount of community does not satisfy its internal incentive constraint, and so the number of exchanges within the community must pass a threshold before community reciprocation can be sustained. Communities need some critical level of interaction in order to function, given their self-enforcement, and so they either exist above that critical level or not at all. As policing becomes more expensive, community exchange is increasingly used, until a second point of discontinuity: eventually one shifts completely away from exchange on a market and entirely to doing tasks within one's own limited community. This comes from the fact that policing must happen at some minimum level in order to make the market function, and thus there is minimal effective scale of markets as well.

It is important to emphasize that both of these discontinuities come in a completely smooth system without any fixed costs. The minimal scale at which both community and the market must operate come from incentive constraints that require a minimal level of perceived punishment - either in terms reciprocation or by the size of the police force.

This provides sheds important light on the relationship between formal and informal institutions: community and markets both require a minimum scale, and once one pushes either above a certain level, they must jump upwards and displace the other altogether. There are strong complementarities in some range, but eventually there are also sharp substitution effects.

With the analysis of the base model in place, we then provide three further investigations.

A first investigation is that we examine the supernatural punishment and moral reasoning inherent in many religions. We model religion as operating at two levels. One is that it is like a community within which people know and trust each other via repeated interactions and exchanges. In this regard it is simply a special case of the communities discussed above. The second, "supernatural punishment", is that people believe that there are gods who will punish them if they fail to obey certain norms of behavior. This might also or instead involve an indoctrinated moral code and "guilt" so that a person feels badly when undertaking certain behaviors. Such beliefs can be useful in enforcing behavior, but can also be costly to instill in a population (Levy and Razin, 2012; Campante and Yanagizawa-Drott, 2015; Power, 2017; Schaumberg and Flynn, 2017).

The supernatural punishment or guilt comes regardless of whether one is punished by a community or law enforcement, and thus it is not complementary to the other forms of enforcement. Effectively, it substitutes for them, as the greater the belief in supernatural punishment for cheating on a contract, the less other enforcement is needed. However, since it changes the incentive constraints – it alters the complementarity between community and policing. In particular, as we show, for low costs of policing it removes the complementarity, but then for a medium range of costs it enhances and extends the complementarity between the other two since it reduces the scales needed to have either the community or the market function.

In addition, we show that there are two conditions for supernatural punishment to make large improvements on welfare: the cost of policing is in an intermediate range, and the religious effect amplifies the complementarity; and the supernatural belief applies to all transactions, even with strangers on the market. These conditions echo a pattern documented in Norenzayan et al. (2016); Roes and Raymond (2003); Henrich et al. (2010), that beliefs in "Gods" and other moralizing exist in relatively larger societies; whereas small societies/religious groups can govern themselves with other forces and without any supernatural beliefs or other moralizing (just as "community" in our context). As maintaining religious beliefs in a society can be costly, it is important to have both scale and scope of the incentive effects.

Our second further investigation is to explore how corruption affects equilibrium and welfare. There is a very basic effect that corruption increases the cost of policing: one has to pay more to get the same effective enforcement out of a police force. The other effect is that there are 'false-arrests' so that people are "caught" and fined even if they did not really commit a crime. This more subtle effect changes the interaction between policing and community by lowering the informativeness of someone being arrested as evidence of a crime. This also decreases the value of a reputation and the future value of being in a community since one faces a chance of being ostracized even when behaving well. More generally, if one has a high expectation of being caught by the police for a crime, then community loses value. According to Pettit and Western (2004), nearly sixty percent of African American males who did not earn a high school degree spent time in prison by the time they were 35. (See also Loury et al. (2008).) Not only does the time in prison lower interaction with their original communities, but also the subsequent ostracism and difficulties faced by ex convicts leads to diminished expectations of future community interactions from an early age. These decreased incentives outside the community and within, and disrupts their complementarity. As we show, together with the cost of ostracism, this lowers the complementarity between community and policing and reduces the range in which they are used together.

Eventually, if corruption becomes so high that the community loses trust in the police, then it no longer ostracizes its members who are "caught", which then completely destroys the complementarity between policing and community. This means that small changes in corruption can lead to discontinuous drops in the effectiveness of policing and welfare. We discuss cases in which loss of faith in policing has led to changes in ostracism of ex-convicts by communities.

Finally, our third further investigation involves the growth of formal government. If investments are needed to grow a government and police force, then we show that effectiveness of a community can enhance the progression to grow a government, while potential corruption can undermine it.

Related Literature

Ours is not the first study of the co-existence of formal and informal exchange. For example, there are models in which people can choose between formal markets and informal exchange, such as Kranton (1996), as well as discussion of how people's membership in clubs has changed over time and how that correlates with lower trust (e.g. Putnam (2000)). There is even evidence that the introduction of a formal credit market can erode social relationships Banerjee, Chandrasekhar, Duflo, and Jackson (2018). There are studies of how community enforcement can substitute for other forms of enforcement or exist in different balances across cultures (Greif and Tabellini, 2010, 2017), and how willing a community is to participate in policing (whistle-blowing) enables enforcement (Acemoglu and Jackson, 2017). There is also ample evidence that market and/or state can function well on a large scale in the right circumstances (e.g., Acemoglu, Johnson, and Robinson (2001); Persson (2002); Tabellini (2010); Besley and Persson (2011); Acemoglu and Robinson (2012); Bednar and Page (2017)).

Perhaps the most closely related of the previous literature, are studies of how the size of a community matters in terms of how effective it is at enforcing behavior, and when it is better to rely instead on a government for policing. In particular, Dixit (2003a,b) shows how community enforcement can do worse than an effective government, and how the size of the community matters - with medium sized communities doing worse than both smaller communities or larger government-based communities.

The key way in which our work differs from the previous literature is that we are focused on the *complementarity* between community and formal government, and the importance of using them together, rather than the circumstances under which either or both thrive. We do not examine the size of the community in terms of how many people it encompasses, but instead on the relative fraction of exchanges that it handles. We examine the interaction between informal and formal enforcement, rather than the substitution of one for the other.

Our modeling builds upon a vast literature that shows that communities can be effective, locally, in overcoming obstacles to collective action and cooperation, and facilitating the provision of local public goods and sharing of resources and the settling of disputes (e.g. Ostrom (1990); Tsai (2007); Ellickson (2009); Xu and Yao (2015)). This is bolstered by a set of models and theories of community enforcement (Ardener, 1964; Coleman, 1988; Ostrom, 1990; Raub and Weesie, 1990; Besley, Coate, and Loury, 1993; Fearon and Laitin, 1996; Anderson, Baland, and Moene, 2009; Lippert and Spagnolo, 2011; Kandori, 1992;

Tsai, 2007; Mihm, Toth, and Lang, 2009; Jackson, Rodriguez-Barraquer, and Tan, 2012; Xu and Yao, 2015; Ali and Miller, 2016), reputation Spagnolo (1999); Mailath and Samuelson (2006), and even of religious enforcement (Levy and Razin, 2012). We then put this to work in conjunction with formal policing.

Other authors have made the point that contracts are necessarily incomplete, and so some things have to be handled outside of formal contracting: thus there are situations in which both formal and informal enforcement are needed. This is a major foundation for theory of the firm that fostered a huge literature (e.g., see Holmstrom and Tirole (1989); Hart (1995); Shleifer and Vishny (1997); Holmström and Roberts (1998); Dixit (2011) for surveys). This can lead to complementarities as informal relationships can reduce uncertainty about what will happen and thus enable formal contracts that might not work otherwise; and vice versa some formal enforcement can reduce the incentives to cheat on informal arrangements (e.g., MacLeod and Malcomson (1989); Poppo and Zenger (2002); Lazzarini, Miller, and Zenger (2004)). Also building on asymmetric information, but on selection rather than moral hazard, Bodoh-Creed (2017) shows that as public institutions attract more untrustworthy people, that can leave a more trustworthy pool of people for the private-order institutions. These analyses are all completely different from our analysis. Instead of building on any uncertainty, our approach is built directly on complementarities in enforcement in one type of interaction due to consequences in another. Thus, our analysis is complementary to the previous literature on uncertainty and which exchanges should be handled formally versus informally.

Our extension regarding supernatural punishment, guilt, and moral codes, relates to a literature on religious beliefs. Empirical studies show that supernatural beliefs facilitate cooperation in human groups (Atkinson and Bourrat (2011)) and serve as a costly signaling device that helps to strengthen communities (Power (2017)), that church attendance reduces crime (Moreno (2018)), and can be positively correlated to economic growth (Barro and McCleary (2003)) and growth-promoting economics attitudes(Guiso, Sapienza, and Zingales (2003)). Religious beliefs have also been found to be negatively correlated with innovation (Bénabou, Ticchi, and Vindigni (2015)) and analytic thinking (Gervais and Norenzayan (2012)). Our analysis of religion is stylized, but provides insights into the benefits of religion on enhancing other forms enforcement and their complementarity, which do not exist in the previous literature.

2 Empirical Background

Before presenting our model, we provide a few basic correlations from cross-sectional data. These provide some guidance as to what sorts of variation we see in the formal and informal institutions across countries, and give a sense of what tendencies a model might explain.

2.1 Description of the Data

There are 106 countries included in our data, and our data focuses on 2016. We examine how the log of GDP of a country correlates with a few variables that relate to formal and informal enforcement of transactions.

The measure of formal enforcement of contracts that we use is an index called "rule of law" that is constructed by the World Bank as part of their World Governance Indicators. As they state, "Rule of law captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence." The variable is compiled from a long list of variables that measure enforcement and perceptions of enforcement and compliance.

Informal community interaction and enforcement is captured via a variable from the Gallup World Poll (2016). The variable is "count on to help". This is the fraction of people in a country who answered "yes" when asked "If you were in trouble, do you have relatives or friends you can count on to help you whenever you need them, or not?" We use this variable as a proxy for whether community enforcement is present and people feel that a favor would be granted if needed.

Another variable that we track from the same poll is "religion". It is the fraction of people in that country who answered "yes" when asked "Is religion an important part of your daily life?" This variable captures two things. One is religion is often a measure of informal community in many societies. Secondly, in some cases it also measures beliefs in supernatural rewards and punishments for good or bad behavior.

Table 1 provides descriptive statistics for the key variables of interest, and Table 2 provides their direct correlations with each other.

Table 1: Descriptive Statics

Statistic	N	Mean	St. Dev.	Min	Pctl(25)	Median	Pctl(75)	Max
lngdp	106	8.163	1.347	5.705	7.025	8.237	9.074	10.962
rule.of.law	106	−0.272	0.886	−2.371	−0.798	−0.391	0.059	1.927
count.on.to.help	106	0.783	0.124	0.290	0.720	0.805	0.880	0.950
religion	106	0.762	0.235	0.190	0.612	0.870	0.950	0.990

For easy interpretation of the variables other than log of GDP, the other variables are normalized by subtracting their means and dividing by their standard deviations.

Table 2: Correlation Matrix

	lngdp	rule.of.law	count.on.to.help	religion
lngdp	1	0.780	0.631	-0.679
rule.of.law	0.780	1	0.451	-0.584
count.on.to.help	0.631	0.451	1	-0.543
religion	-0.679	-0.584	-0.543	1

Figures 1-3 show the raw relationships between log of GDP and Rule of Law, Count on to Help, and Religion, respectively.

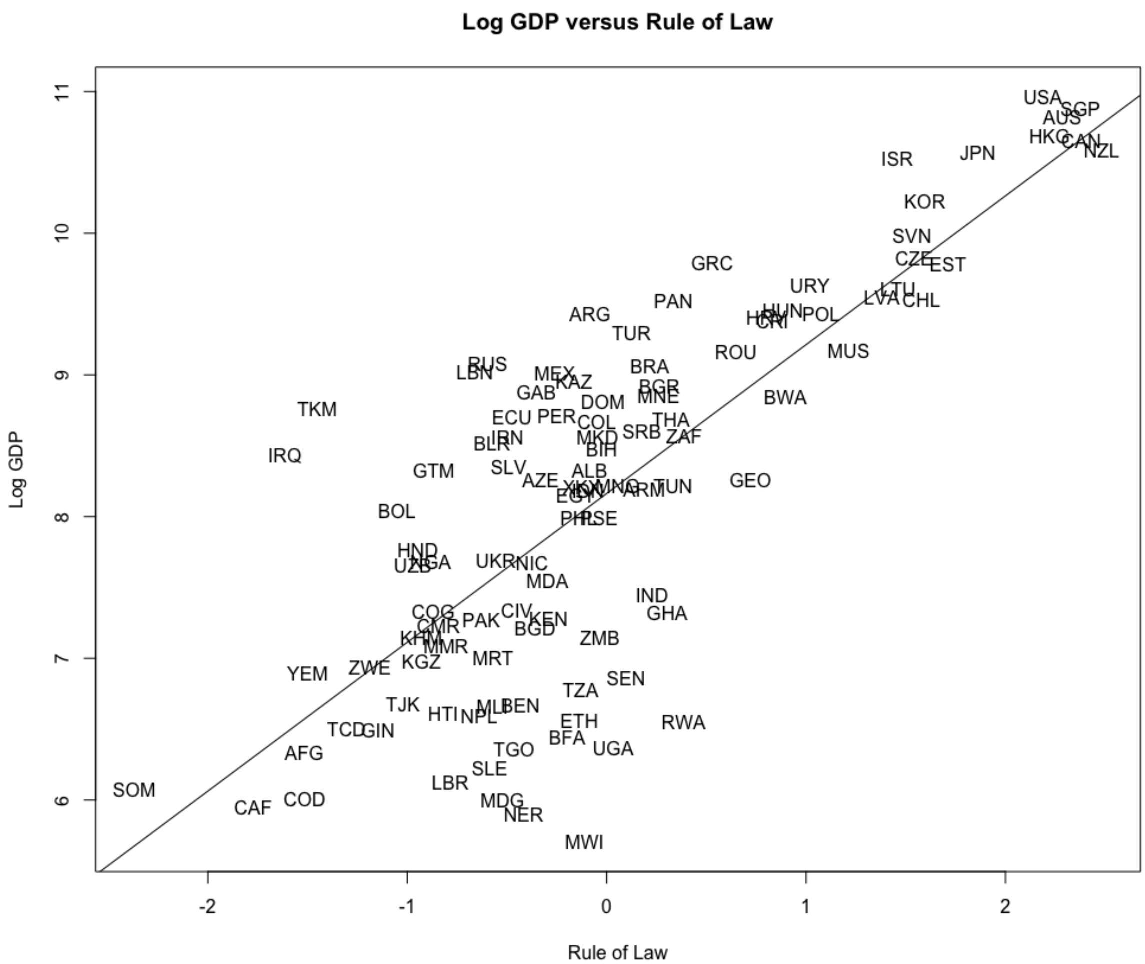


Figure 1: Ln of GDP plotted against Rule of Law.

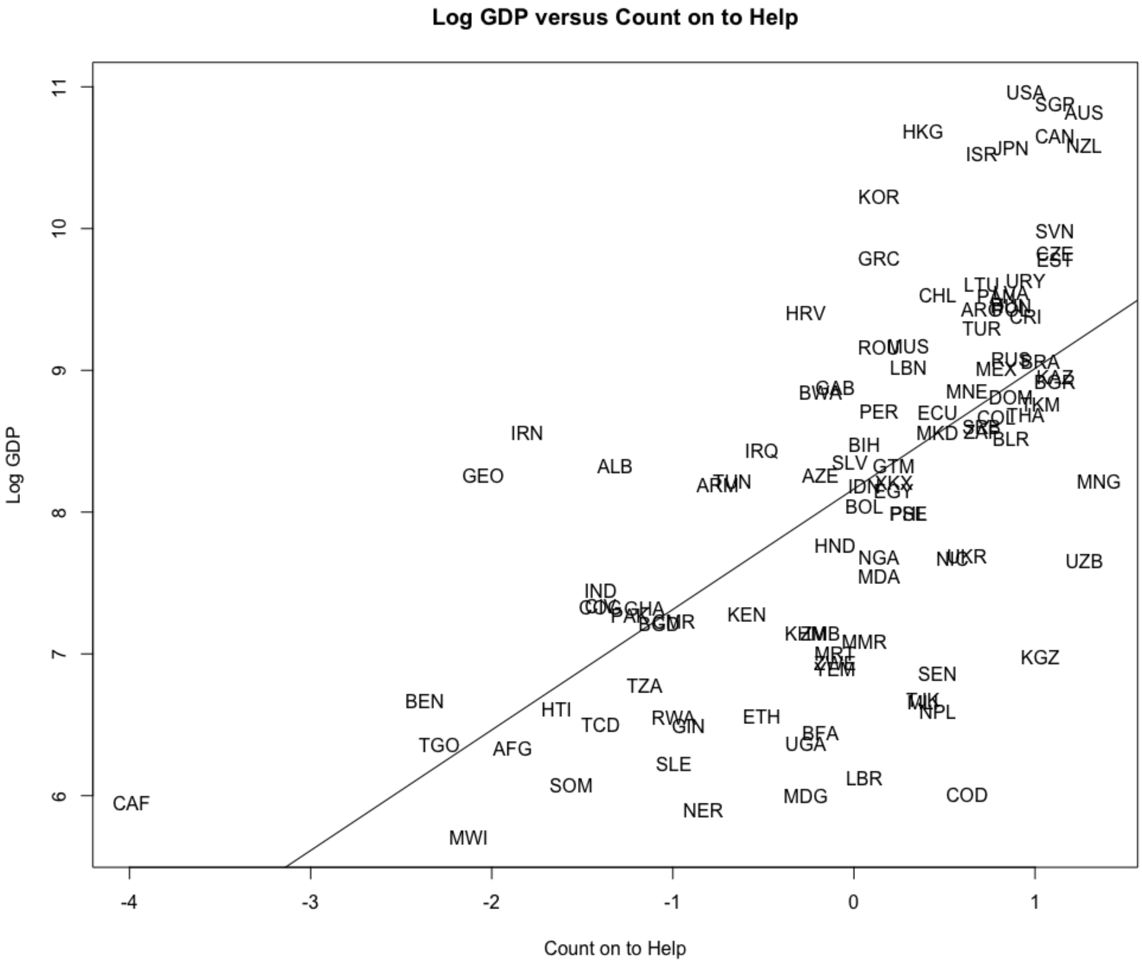


Figure 2: Ln of GDP plotted against Count on to Help.

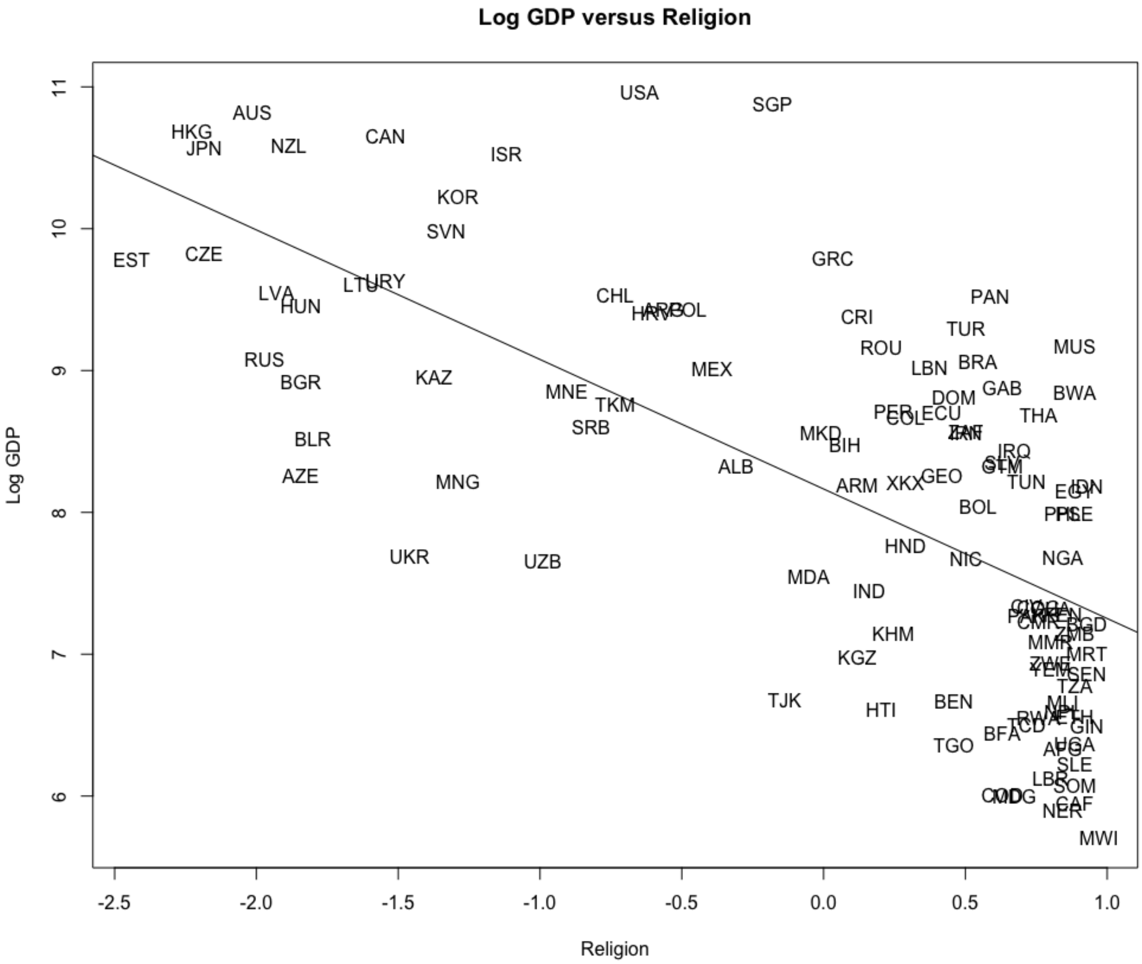


Figure 3: Ln of GDP plotted against Religion.

2.2 The Relationship Between Production, Community, Rule of Law, and Religion

We first examine how (log) GDP varies with 'Rule of Law' and 'Count on to Help', as reported in Table 3.

First, in all specifications, separately and together, 'Rule of Law' and 'Count on to Help' are both significantly, and positively related to GDP. Moreover, the magnitudes of the relationships are strong.

Most importantly, when combined, 'Rule of Law' and 'Count on to Help' have a positive interaction term – suggesting a complementarity: the effect of enforcement is higher when there is more community. Thus at least one measure of community acts as a complement to formal government enforcement in predicting output.

Next, we briefly discuss the relationship between religion and productivity, which is

Table 3: Log GDP regressed on Rule of Law and Count on to Help

	Dependent variable:		
	ln GDP		
	(1)	(2)	(3)
Rule of Law	1.050***		0.770***
	(0.083)		(0.086)
Count on to Help		0.850***	0.544***
		(0.102)	(0.087)
Rule of Law × Count on To Help			0.146**
			(0.071)
Constant	8.163***	8.163***	8.098***
	(0.082)	(0.102)	(0.077)
Observations	106	106	106
R^2	0.608	0.398	0.718
Adjusted R^2	0.604	0.393	0.709
Note:	*p<0.1; **p<0.05; ***p<0.01		

captured in Table 4.

Table 4: Log GDP regressed on Religion, Rule of Law and Count on to Help

	Dependent variable:			
	ln GDP			
	(1)	(2)	(3)	(4)
Rule of Law		0.827^{***}	0.669^{***}	0.758^{***}
		(0.096)	(0.088)	(0.113)
Count on to Help			0.290^{***}	0.330^{***}
			(0.099)	(0.104)
Religion	-0.914^{***}	-0.499^{***}	-0.582^{***}	-0.557^{***}
	(0.097)	(0.096)	(0.123)	(0.124)
Rule of Law × Religion		0.113	0.126	0.021
		(0.075)	(0.083)	(0.119)
Rule of Law × Count on to Help			0.304^{***}	0.222^{*}
			(0.090)	(0.112)
Count on to Help × Religion			0.450^{***}	0.414^{***}
			(0.136)	(0.138)
Rule of Law × Count on to Help × Religion				0.131
				(0.106)
Constant	8.163^{***}	8.228^{***}	8.342^{***}	8.323^{***}
	(0.097)	(0.086)	(0.092)	(0.093)
Observations	106	106	106	106
R^2	0.460	0.691	0.772	0.775
Adjusted R^2	0.455	0.681	0.758	0.759
Note:		*p<0.1; **p<0.05; ***p<0.01		

'Religion' is negatively related with productivity in its direct effect. There is a positive interaction between 'Religion' and 'Count on to Help'. It has positive but insignificant interactions with 'Rule of Law' and the combination of 'Rule of Law' and 'Count on to Help'

3 A Model of Community and Government Enforcement

We now turn to our main results: a model and investigation of the interaction of formal and informal enforcement of behavior. We begin with a description of the base model.

3.1 Tasks and Time

A set of agents is divided into a set of communities. As will become clear, the specification of who is in what community is not vital to the model, but to fix thoughts think of a finite set of equal sized communities.

Generally we think of the number of agents per community to be relatively small and the number of agents overall to be large, so that agents can easily know and keep track of everyone within their community, but do not track or recognize people outside of their community. We do not examine issues regarding the size of the population in a community as those have been explored elsewhere (e.g., Dixit (2003a,b)), and just presume that communities are small enough so that people are quickly aware of any deviations from social norms within their community. It could be interesting to endogenous the size of community and relate it to various parameters in the model, but that is beyond the scope of the present paper.

Time proceeds in discrete periods $t \in \{1, 2, \ldots\}$. Agents discount time according to a common discount factor $\delta \in (0, 1)$.

Every agent has to complete a task in each period t – cooking, doing laundry, taking care of kids, fixing their house, getting medical help, producing some good, etc. – and has a capacity to do one task during the period.

In any given period, an agent can either complete their own task, some other agent's task, or consume an outside option (leisure or some exogenous wage). The opportunity cost of effort (leisure, self-employment, outside wage, etc.) is normalized to be 1 per unit of time.

The cost if the agent's task is completed by the agent directly, by someone in the same community, or by a outsider, is t_s, t_c, and t_o, respectively. We let

$$t_s > t_c > t_o > 0.$$

This ordering represents the gains from trade in a simple stylized way.

Within a community of a given fixed size, the savings from someone else in the community doing the task is $t_c < t_s$. Thus, agents can specialize activities within a community and trade tasks. More generally, there are larger economies of scale and scope in doing tasks when we expand the possibility of trading tasks throughout the full society, as well as gains from specialization and comparative advantage. This results in the lowest cost when tasks are exchanged across the full society, and so $t_o < t_c$.

There may be some tasks where the given person him or herself is the best qualified, and so think of the tasks that we model as the marginal tasks that agents must complete and someone else is better at doing at a lower cost.

For example, as a teacher, Bob can tutor a friend's child or answer some questions, or he may teach a number of kids in a formal employment relationship. He might not perform in the community by failing to show up when his friend needs help, or on the market by not putting in any effort to design a lesson plan. Bob may also have a task: he needs some medical advice. He can ask a friend who has some medical training for some simple advice, or can go to the market for more serious help.

We abstract away from the precise matching of who is doing things for whom, and simplify by having all tasks have a similar cost structure. Of course, there is more heterogeneity in applications, but the simplified model is already quite complex to analyze and keeps the intuitions relatively clear, and so we leave extensions to heterogeneous cost structures for future research.

Efficiency (ignoring incentives and enforcement costs) requires that all the tasks be exchanged in the full society. It is also better to have a task done by other community members than a person him or herself, if we restrict attention to just a community.

3.2 Equilibrium and Incentive Constraints

For tasks done inside the community, things work by reciprocation and there is no formal enforcement. You may help a colleague by teaching their class, or watch a neighbor's pets while they are away, or watch their kids, etc., and the incentives are based on future reciprocation. If one fails to perform a task, the community can punish the agent by ostracizing the person. This is a key aspect of community: it is small enough so that people can track who has not behaved well in the past and thus can collectively punish that person.

For tasks done outside of the community, things work by random policing and fines. You may contract with someone to repair your car, manage your investments, etc.

The amount of policing also includes things like the enforcement of property rights and contracts by courts. For instance, if one sues a person or company for breach of contract will that suit be heard in a reasonable time, or are there huge backlogs of pending cases. How easy is it to evict someone? Can a landlord falsely evict someone and get away with it? How easy is it to fire a worker who fails to do their job? Can a manager be punished for harassing workers? The answers to these questions differ dramatically around the world and even within different jurisdictions in the same country. We distill this into a single parameter ϕ that we refer to as a probability of being caught by the policing, but it should be interpreted as embodying the full justice system including the delineation of property rights and rules, the policing and monitoring of behavior, the ease of bringing lawsuits, and the judicial enforcement of rules and property rights.

Most importantly for the complementarity, if someone is caught and fined for cheating for not delivering on a task they are exchanging on the market, then one's own community may learn about this and then ostracize the agent. For instance, if an agent is caught stealing money that he or she is managing, then that arrest may heard about by the rest of his or her community, who may then react by no longer trusting or interacting with the agent.

We do not explicitly model the barter or pricing of tasks on the market, which cancel out given the symmetry of the model. We instead directly model the incentives to deliver on an agent's side of performing a task.

It is easy to see that to understand the efficient frontier of equilibria all tasks are shared/traded - or else there is simply autarky. Completing just some fraction of tasks by one's self will never be part of an efficient equilibrium, since doing more things one's self just makes the incentives constraints harder to satisfy since the value of future interaction is lower, which decreases incentives to do others' tasks when asked. Thus, to characterize efficient equilibria, we examine incentive constraints when all tasks are exchanged either within community or outside.

To define equilibrium, we start with the incentive constraints that must be satisfied.

Let q denote the fraction of one's tasks done within community and $1 - q$ the fraction done outside of the community. An easy way to think about this, is that there is a convention of which tasks are marketed and which ones are done within a community.

If an agent is doing a task for someone within their community then the penalty for not doing the favor will be that the agent's future tasks that were supposed to be done within the community must be done by him or herself instead. If an agent fails to do a task for an outsider, then a formal enforcement applies as if a contract has been broken, with a random possibility of being caught by a police force and fined. In addition, the agent's own community might learn about the "crime" and also ostracize the agent.[2]

Incentives for Reciprocation within a Community

Let

$$V = \frac{\delta(t_s - t_c)}{1 - \delta}$$

denote the future discounted change (per community task) in costs that an agent would face

[2]Our model is extreme in that cheaters are always caught within the community, and that people know everyone's community past but not necessarily their outside past. In reality there will be noise in all directions. The model is rich enough as a first-order approximation, and it does not appear that adding noise on any of these dimensions does anything but complicate expressions without adding much new insight. We comment in the concluding remarks on where the most promising directions for adding noise appear to be.

for having to do tasks him or herself that were supposed to done by the community. In autarky a person faces costs of $\frac{t_s}{1-\delta}$, while by cooperating those costs are $\frac{t_c}{1-\delta}$.

An agent can fail to complete his or her task in a given period, but then faces a loss of reciprocation in the future. The maximum penalty is going to autarky.[3]

The incentive constraint for doing a task within one's community is thus:

$$t_c \leq qV = \frac{\delta q(t_s - t_c)}{1-\delta}. \qquad (IC^{com})$$

This applies to the q fraction of community tasks.

This constraint simplifies to

$$q \geq \frac{t_c}{V}.$$

In what follows, we focus on the case in which $V \geq t_c$ so that there is some possibility of having a community-enforced equilibrium, otherwise the model becomes degenerate and the only option is either autarky or entirely outside enforcement.

Incentives to Abide by an Agreement under Outside Exchange

If an agent fails to perform a task for an outsider, the agent is caught by the police with a probability ϕ, and then pays a fine f.

While we do not model it here, ϕ itself could depend on whistle-blowing and reporting of infractions by individuals to the police (e.g., see Acemoglu and Jackson (2017)). For instance, if a consumer is cheated then that person may bring a criminal or civil suit against the other party.

In addition, ψ denotes the probability that, when an agent who is caught and fined by the police, that fact is then learned about by his or her own community. In many contexts, ψ can be quite high - as in the contexts that we noted in the introduction: such as the auto-da-fé, tattooing, etc. This drives the complementarity between community and police enforcement. If $\psi = 0$, then there is no complementarity. A community can ostracize its members who are caught by the police.[4] This provides extra incentives.

The incentive constraint for an agent to complete a task for someone outside of the community is then:

$$t_o \leq \phi f + \phi\psi qV, \qquad (IC^{out})$$

[3] Less drastic punishments can be part of an equilibrium. Examining the strongest incentives provides a characterization of the equilibrium frontier, and so we focus on the most drastic punishment.

[4] Again, there can be many equilibria and some might not involve ostracism. However, ostracism provides the maximum incentives and can be part of an equilibrium, and so we study this strongest incentive constraint to characterize the equilibrium frontier.

which becomes

$$\phi \geq \frac{t_o}{f + \psi q V}.$$

Note that the value of community in providing incentives, qV, is proportional to q. A larger fraction of community tasks, q, results in a more valuable reputation within one's community, and will enhance the complementarity between community and police enforcement.

Built into the statement of the incentive constraint is that someone who has cheated and been caught once, will not benefit from doing so again. This can be justified in two ways. On is that the police keep a list of agents who have been arrested: once an agent is caught the agent is on parole and monitored forever after - so ϕ increases. Alternatively, the fine or sentence for a repeat offender is higher than for a first-time offender. Both of these are seen routinely in law enforcement. Without this, once arrested and ostracized by their community an agent will prefer to cheat on the outside market forever. This leads to a different outside incentive constraint that is more complex but it still has all of the same comparative statics as this simpler one. [5]

We assume f is exogeneously fixed, and finite (more on this below). In addition, we assume $f > t_o$ in what follows. This condition together with the assumption that individuals being arrested will be monitored for sure provide enough incentives for those individuals not to deviate in future outside interactions, and hence IC^{out} is the correct constraint.

To fix ideas, think of someone who fails to report taxes from some transaction. If they are caught once, then they are audited for sure rather than just being audited with probability ϕ in all future interactions. Whether their friends and neighbors learn about this transgression and ostracize the person may be random and is captured by the parameter ψ. Thus, ψ could depend on how well police activity and crimes are publicized, and the extent to which community members pay attention to such publicized lists. More generally, "ex-convicts" are monitored in a variety of ways, and whether their past criminal record is known to a community differs by region and crime.

[5] The other incentive constraint is $t_o \leq \phi f + \phi\psi \left(qV - \frac{\delta}{1-\delta}(1-q)(t_o - \phi f) \right)$. The added term on the right hand side accounts for the added the value from cheating on the market forever after if an agent is ostracized from her community (as then the agent anticipates that the outside constraint will no longer be satisfied if it was binding with ostracism). A transformation of the equation gives

$$t_o \leq \phi f + \frac{1-\delta}{1-\delta q} \phi \psi q V,$$

whose right hand side is still increasing in both q and ϕ and generally has the same properties as the simpler incentive constraint. Which incentive constraint is more relevant would depend on context and whether police monitor ex-convicts more closely than the rest of the population, or fine repeat criminals more drastically. For the sake of exposition, we assume that they do.

Equilibrium When we refer to *equilibrium* we mean a convention of which fraction of tasks are done within community, q, with the remaining $1-q$ done on the open market, such that the incentive constraints are satisfied: if $q > 0$ then IC^{com} is satisfied and if $q < 1$ then IC^{out} is satisfied.

This is a shortcut for defining equilibrium, as opposed to formally defining the extensive form game and the subgame perfect equilibria of that game. The notation for defining matchings and histories here would become cumbersome, with the end equilibrium outcome possibility set remaining the same. Given the complexity of the analysis below, we adopt the simple route of working with a definition directly in terms of incentive constraints (much as the principal-agent and contracting literatures have done).

Which q's can be equilibria depend on the level of policing ϕ (and all the other exogenous parameters that define the setting). By the assumption that $V \geq t_c$, $q = 1$ is always an equilibrium. With the assumption that $f > t_0$, then when $\phi = 1$ is it also possible to have $q = 0$ (all market) be an equilibrium.

We can think of ϕ as being a choice variable of a government or planner, and thus can see how welfare works as a function of ϕ, q combinations for which q is an equilibrium.

The combination of ϕ, q for which the incentive constraints are satisfied are pictured in Figure 4.

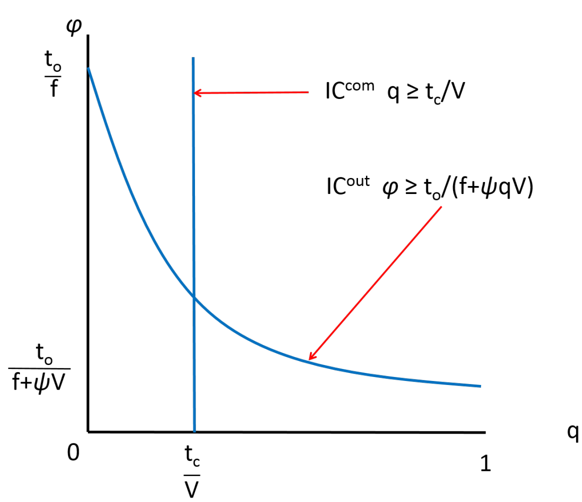


Figure 4: The community and outside incentive constraints. Higher levels of policing and tasks done within community pass both incentive constraints.

The potential welfare-maximizing points are pictured in Figure 5.

It makes no sense to use more ϕ than is necessary to satisfy the incentive constraints, as policing is costly (more on this below). This leads to three potential regions for welfare-maximization: either just one but not both of community and policing is used (so q is either

0 or 1 and then the corresponding incentive constraint must hold), or both are used and then both constraints must hold.

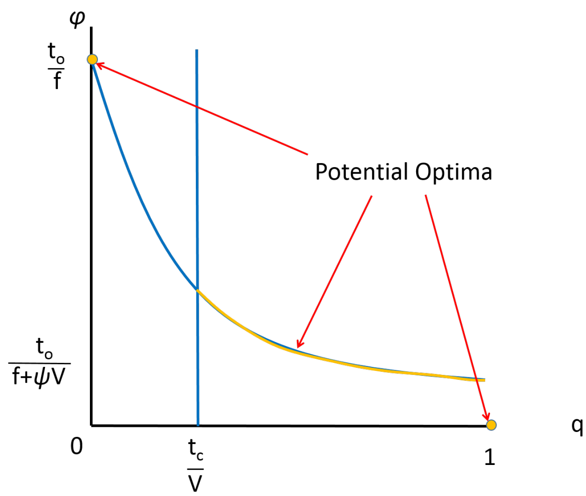


Figure 5: The potential optima involve satisfying both constraints (in which case it makes sense to choose the lowest ϕ), or else going to a corner in which either all community is used $q = 1$, or all market is used $q = 0$ and then the outside constraint binds.

A Remark on Fines

One can always make sure that the incentive constraint IC^{out} holds with very little policing by setting f to be huge.

There are (at least) three reasons that this is not done.

First, there is a moral concept of 'cruel and unusual punishment' or that a 'punishment should fit the crime.' For instance, the Eighth amendment to the US constitution states that "Excessive bail shall not be required, nor excessive fines imposed, nor cruel and unusual punishment inflicted," and such policies date back to English Law in 1689. The UN's Universal Declaration of Human Rights states that "No one shall be subjected to torture or to cruel, inhuman or degrading treatment or punishment." This has a long history, for instance Hamarabi's code states: "If a man destroy the eye of another man, they shall destroy his eye. If one break a man's bone, they shall break his bone. If one destroy the eye of a freeman or break the bone of a freeman he shall pay one gold mina. If one destroy the eye of a man's slave or break a bone of a man's slave he shall pay one-half his price."

A second justification for this is that there may be errors made and with a positive probability of errors, then huge fines for small offenses are not welfare maximizing.

A third reason is that it can be costly for a government to punish - especially when this involves imprisonment or execution.

We do not model these reasons, but simply take it as given that f is a finite exogenous number - generally a fine "commensurate" with the offense - and so then a positive ϕ is necessary for incentives.

3.3 The Optimal Mixture of Community and Policing

We now characterize the welfare-maximizing level of policing ϕ and equilibrium q, as a function of the setting.

The societal welfare includes the costs of policing as well as the total costs of doing tasks.

Let $C(\phi, q)$ be the (per-capita) cost of policing needed to support detection probability ϕ, when $1 - q$ is the fraction of tasks done on the market.

We assume that C is increasing in ϕ, so a larger police force is needed to catch people with higher probability, and C is non-increasing in q - so that it is weakly more costly to police more transactions. We assume that C is differentiable in both arguments, but only when $\phi > 0$, so that we allow for a discontinuity when $\phi = 0$, so that there can be a fixed cost that kicks in for positive policing.

Two canonical examples are:

(i) $C(\phi, q) = \phi(1 - q)$ for some $c > 0$, so that the amount of police is per probability of catching people per outside transaction, and

(ii) $C(\phi, q) = \phi$ for some $c > 0$, so that the amount of police is per probability of detection per capita.

One can imagine many cases in between. For simplicity, we draw most of our figures for case (ii), but our results apply to more general cost functions.

We take C to be quasi-convex in (ϕ, q). This allows for costs to adjust with q and for having cost savings with scale of $1-q$ - having less than per capita costs, just as in (i) above. This is exactly the condition that ensures that the lower contour sets of the minimization program are convex - and so are precisely what is needed to ensure a well-behaved optimal equilibrium problem.

Maximizing the welfare of the society is equivalent to minimizing the total costs of doing tasks plus the cost of policing:

$$qt_c + (1 - q)t_o + C(\phi, q),$$

where this presumes that the incentive compatibility constraints are met. Fines could be consumed by other agents (and do not appear in equilibrium in any case), and so they are not included in the welfare function.

The characterization of the best combination of policing ϕ and equilibrium q is therefore given by the program:

$$\min_{\phi,q\in[0,1]^2} q(t_c - t_o) + C(\phi, q)$$

$$s.t. \quad q\left(\frac{\delta q(t_s - t_c)}{1-\delta} - t_c\right) \geq 0, and$$

$$(1-q)\left(\phi f + \phi\psi\frac{\delta q(t_s - t_c)}{1-\delta} - t_o\right) \geq 0$$

where q in the first constraint captures that IC^{com} is only needed if $q > 0$, and similarly $1-q$ in the second constraint captures that IC^{out} is only needed if $q < 1$.

The various potential solutions to this program are pictured in Figures 6 and 7. Again, we draw things for the case of $C(\phi, q) = c\phi$, but most of our results (unless otherwise stated) apply more generally.

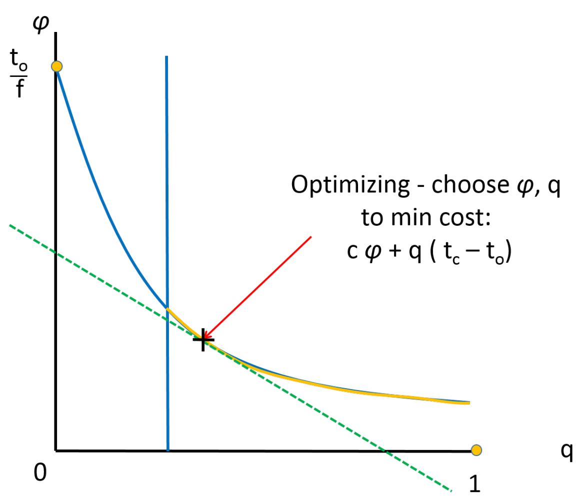
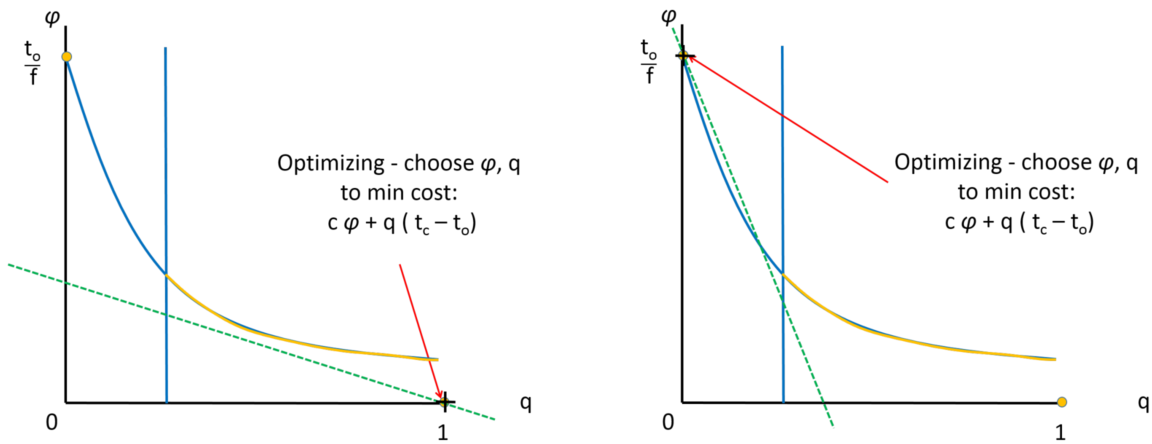


Figure 6: The optimum - minimizing $q(t_c - t_o) + c\phi$ when c is in a middle range.



(a) For high costs of policing, c, the solution is all community .

(b) For low costs of policing, c, the solution is all market based.

Figure 7: There are corner solutions where only community (for high costs, panel a) or only market/outsiders (for low costs, panel b) are used. Note that in (b) the line is not tangent to the outside IC curve, since the tangent point would not be feasible as it would involve an internal q but the community IC constraint would be violated.

The policing IC^{out} constraint binds unless it is so expensive that only community is used, as in panel (a) of Figure 7. We emphasize that in (b) the line is not tangent to the outside IC curve, since the tangent point would not be feasible as it would involve an internal q but the community IC constraint would be violated. Thus, in that case it is the outside IC constraint with $q = 0$ that must hold.

In contrast, the community constraint only binds when there is a particular corner case: using the minimal amount of community (that satisfies its incentive constraint) to help increase the cost of being caught by the police, as in Figure 8. Again, in this case the line is not tangent to the outside IC curve, but instead hits at the corner where both IC constraints hold.

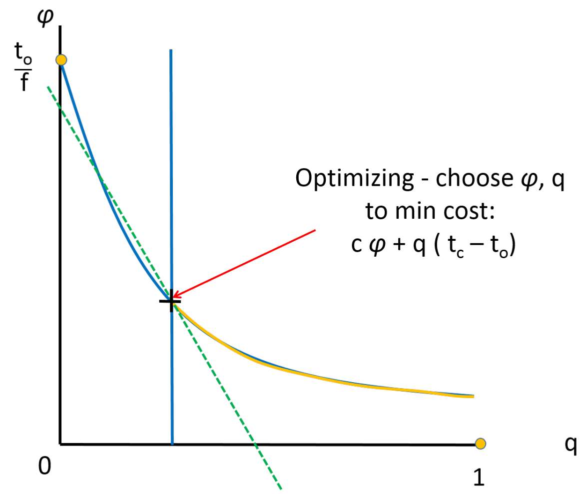


Figure 8: The community IC constraint only binds (generically) at a corner when it is better to have the minimum amount of community to (that satisfies its incentive constraint) to help increase the cost of being caught by the police.

3.4 Comparative Statics in the Cost of Policing, c

We now provide more detailed comparative statics in costs of policing. In order to do this, we break C into two parts:

$$C(\phi, q) = cP(\phi, q),$$

where we can interpret $P(\phi, q)$ to be the police force needed to get a detection probability of ϕ on a market of size $1-q$, and where c is a unit cost of police. Assume $P(\phi, q) > 0$ whenever $\phi > 0$ and $q < 1$ so that formal policing does not come for free. This parametrization allows us to do comparative statics in c while considering both scenarios (i) and (ii) from above, as well as many other forms of the cost function.

A larger c can correspond a more costly or relatively labor-intensive policing technology, e.g., in more rural, poorer, or less developed societies. For instance, c would be higher in a policing system that relies heavily on foot patrols, compared to a system that relies on less costly technology. Thus, richer and more developed countries may have lower c's than poorer developing states. In addition, c captures the *effective* cost in the sense that in a corrupt system it is more costly to deliver the same probability of enforcement due to moral hazard on the part of the police or judges, and hence corruption can be partly captured by larger c. Section 6 provides a more extensive look at corruption, but an inflation of c captures a basic impact of corruption. In addition, a higher c can be due to an ineffective or overloaded court system. For example, in some cities it can be very difficult and time-consuming to evict a tenant who fails to pay rent. This leads to less renting on the open market.

We hold other parameters fixed (such as t_c, t_o, t_s, f, ψ and δ) and provide the comparative statics in those other parameters in Appendix A.2.

The figures above suggest how the welfare-maximizing equilibrium mixes of community and enforcement work as we vary the unit cost of policing, c, and here we state that this holds quite generally.

Proposition 1 **(Optimal Community and Policing, and Comparative Statics in c)**

There exists $\overline{\psi} \geq 0$ such that:

1. *If $\psi < \overline{\psi}$ then the optimal level of policing and equilibrium are bang-bang: all-community is optimal if $c > c^* \equiv \frac{t_c - t_o}{P(0,t_o/f) - P(1,0)}$, and all-policing is optimal if $c < c^*$.*
2. *If $\psi > \overline{\psi}$, then there are three thresholds, $c^{out} < c^{mix} \leq c^{com}$, such that*
   - *all community is optimal if $c > c^{com}$*
   - *a high community level, $q \in \left(\frac{t_c}{V}, 1\right)$, is optimal if $c^{mix} < c < c^{com}$,*
   - *the minimal community level, $q = \frac{t_c}{V}$, is optimal if $c^{out} < c < c^{mix}$, and*
   - *all policing is optimal if $c < c^{out}$.*

   Moreover, c^{out} is increasing and c^{com} is increasing in ψ.

The precise term for $\overline{\psi}$ depends on the policing cost function $C(\phi, q)$. In the case in which $C(\phi, q) = c\phi$ it is easy to check that $\overline{\psi} = \frac{f/V}{1-t_c/V}$. The general analysis appears in the appendix.

Without a large enough ψ, the complementarity between policing and community is so low that just using one or the other is always better than working with both.[6] Once complementarities are large enough, then the optimizing choice behaves as in Figures 6 - 8, which is what the proposition states.

To understand the claim that the range of costs for which there is a complementarity and both community and policing are used, i.e., that c^{com} is strictly decreasing and c^{out} is strictly increasing in ψ, is pictured in Figure 9. As ψ increases, the outside incentive constraint becomes easier to satisfy, as there is more implicit punishment from being caught by the police. In terms of which objective functions hit an optimum on the yellow part of the curve, the lower that curve is, the wider the range of c for which that curve contains the optimal point. A larger ψ enhances the complementarity and effectiveness of mixtures in which

[6] For instance, in Figure 8, if the IC^{out} curve was much flatter due to a low ψ, its intersection with IC^{in} would be very high on that curve, and the minimal cost line would always be below it and intersect one of the two extreme points instead.

both community and policing are active - lowering that curve and hence the comparative statics in the cutoff thresholds, while it does not affect the payoff under the all-policing or all-community regimes. Therefore such an increase in ψ expands the region of parameters in which a mixture regime is optimal.

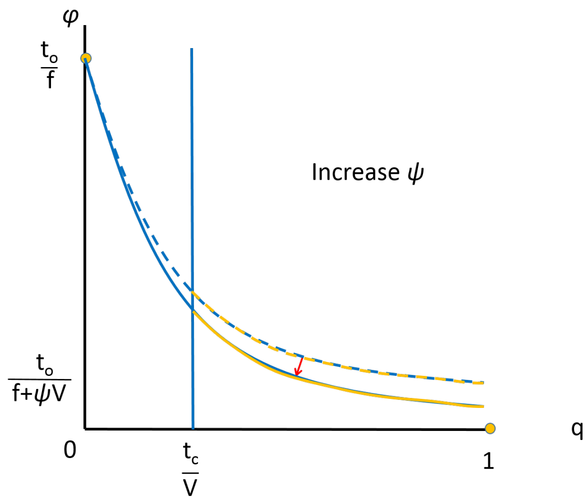
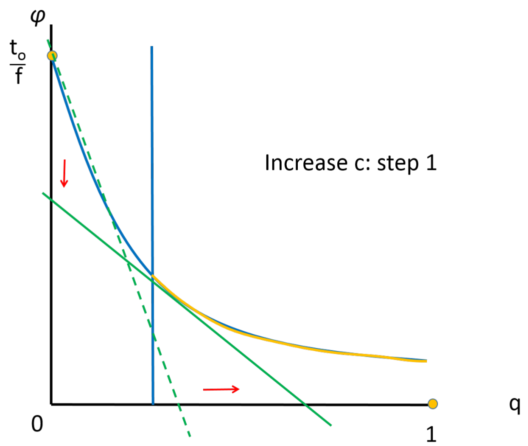


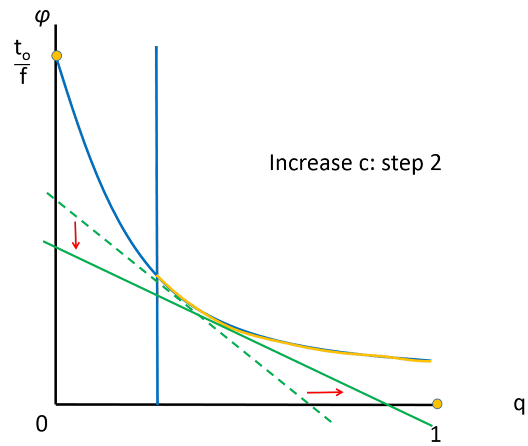
Figure 9: As ψ increases, the outside incentive constraint gets easier to satisfy. More of the potentially optimal region gets used as the constraint is lowered and it hits the optimal objective function for a wider range of c.

The benefits from increasing ψ make it clear why there are so many instances in which authorities publicize convictions, such as those referred to in the introduction. It can be a relatively cheap way of improving enforcement. In fact, even if the fine is 0, with a high ψ formal enforcement can be very effective: an authority does not formally punish the person but does publicize their misbehavior. This is, in part, how the policing of many online platforms works, as well as the way that the enforcement of the 'Gentleman's' rules worked as described by Mokyr (2008) - news of misbehavior and the subsequent loss of reputation and standing in one's clubs and society were strong punishment and worked well even in the face of relatively ineffective fines and courts.

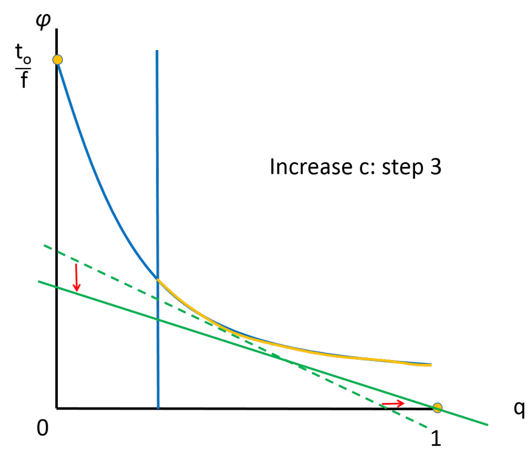
As stated in Proposition 1, there are multiple regimes, depending on which one, or both, of the community and the policing are active. The evolution of that optimal regime, as well as comparative statics within the mixed regime in which both community and police enforcement are used, are depicted in Figure 10.



(a) Starting from a low cost, moving to a medium cost: change from all policing to using a mixture of policing and community



(b) Starting from a medium cost, moving to a slightly higher medium cost: increase the amount of community used



(c) Starting from a medium cost, moving to a high cost: change to all community

Figure 10: Comparative statics as c increases.

The following result holds for both within-regime and across-regime changes.

Proposition 2 **(Comparative Statics in the Cost of Policing c, Part II)** *As c increases, welfare weakly decreases and strictly decreases whenever formal markets are being used. Moreover, the use of community weakly increases and the probability of enforcement ϕ weakly decreases (strictly whenever q increases).*

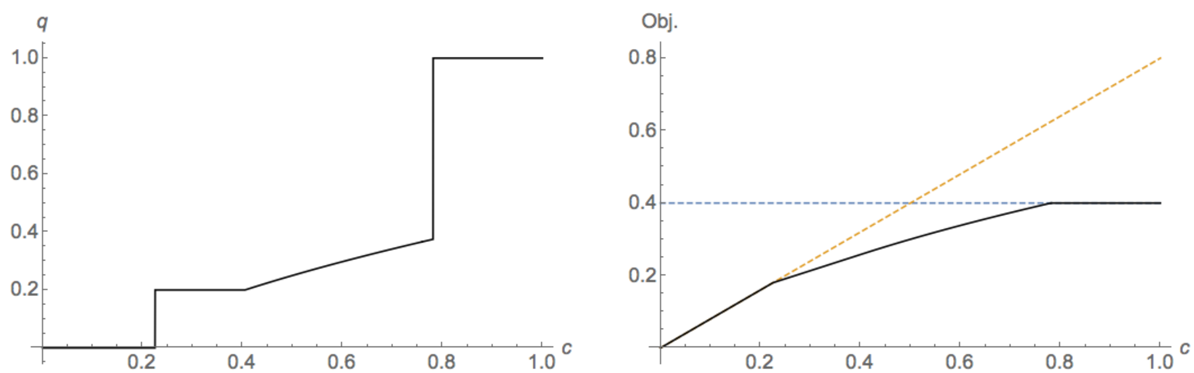
3.4.1 An Example of the Change in Equilibrium and Welfare with Changes in Policing Costs

We illustrate the comparative statics in the model by detailing how welfare and optimal equilibrium structure vary as we change the cost of policing.

For the purposes of this example, we set $t_s = 1, t_c = .8, t_o = .4$, $f = 0.5$, $\delta = 20/21$, $\psi = 1/2$, and cost of policing $C(\phi, q) = c\phi$.

With these parameters, (IC^{com}) requires $q \geq 1/3$. Therefore, the society either does everything outside communities, or else at least a fraction of at least 1/3 within community.

This example belongs to case 2 of Proposition 1, and the thresholds work out to be $c^{com} = 0.225$, $c^{mix} = 0.405$, and $c^{out} = 0.78125$, which characterize the four optimal regimes.



(a) The Fraction of Community Task Provision

(b) Overall Costs (Opposite of Welfare: $q(t_c - t_o) + c\phi$)

Figure 11: Comparative statics in the cost of policing: an example.

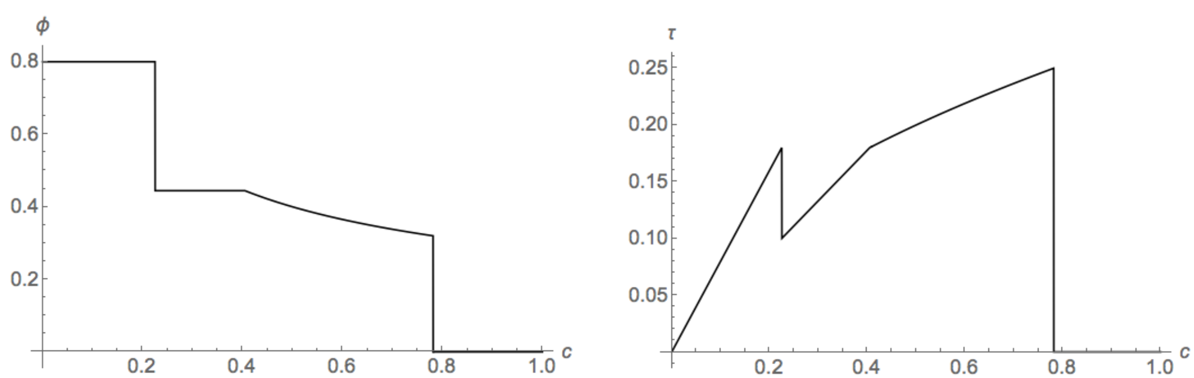
The comparative statics and discontinuities are pictured in Figure 11.

In panel (a) of Figure 11 we see the four regimes and two associated discontinuities. When costs of policing are very low, only policing is used, which corresponds to Figure 7, panel (b). Once we cross the threshold of $c^{com} = 0.225$, then we switch to a regime in which some community tasks are provided, which corresponds to Figure 8. Now community is being used as a complement to policing. This involves a discontinuous rise in the level of community, since community cannot be used without satisfying its incentive constraint, which requires a $q \geq .2$ in this example. Until we get to a cost of policing of $c^{mix} = 0.405$, there is no change in the mixture of community and policing that is used, as it is still most efficient to use the minimal amount of community needed to satisfy the incentive constraint. Once costs are greater than $c^{mix} = 0.405$ (and less than $c^{out} = 0.78125$) the level of community used increases, as using more of it further reduces the amount of policing needed. This corresponds to the optima in Figure 6. Once costs exceed $c^{out} = 0.78125$, then the policing becomes too expensive and it is best to switch to all community, which corresponds to Figure 7, panel (a). Here we see another discontinuity: policing is now more expensive than working entirely within a community, and there is an abrupt change.

It is worth emphasizing that formal policing drops away discontinuously and is not used for a wide range of c, *even though we have not assumed any fixed cost*.[7] The first discontinuous jump up in community use comes from the fact that community enforcement requires a minimal threshold in order for future reciprocation to outweigh current temptation. The second discontinuous jump also does not involve any any fixed cost, but it comes since market incentives require a minimal probability of being caught and thus a minimal expenditure on policing. Thus, there are no optimal equilibria with tiny amounts of community or tiny amounts of market - each must be used in an amount above some threshold or not at all.

In panel (b) of Figure 11 we see the associated rate at which overall costs go up as the cost of policing rises. Things begin in a region in which the rise is one-for-one, as at very low costs all enforcement is by policing. Once we get to the middle range, then there is a mixture of policing and community enforcement, and so the slope decreases. This is the range of complementarity: the overall cost is increasing by less than the cost of policing, since policing is complemented by community ostracism and less policing is needed to achieve the same incentives. Throughout this range, the slope at which costs rise is decreasing, since more substitution is used, which lowers the amount of policing that is needed. Eventually, things switch to entirely community enforcement and overall costs no longer rise with the cost of policing.

Figure 12 pictures the associated changes in the rate of policing ϕ and associated costs of policing, and again the two points of discontinuity are clear.



(a) Amount of policing (ϕ)

(b) Cost of policing ($c\phi$)

Figure 12: More comparative statics in the cost of policing.

[7]This is in contrast to the argument in, for instance Casari (2007), in which fixed costs play an important role in the adoption of a formal institution (charters).

There are many parameters of the model for which we develop comparative statics (discounting, fines, task costs, ψ). As they affect incentives differently, there are interesting contrasts in their comparative statics. For the sake of length, we present them in Appendix A.2.

One interesting set of comparative statics concerns changes in $t_o - t_c$. As a country industrializes and urbanizes, the relative gains from trade on an open market compared to doing everything within community increase. This tilts the objective function and benefits to society towards the market. At the same time, a decrease in t_o also makes the formal incentive constraint easier to satisfy. These combined forces tend to lower the optimal amount of community at work, which is consistent with what is seen in many settings as an economy grows. It does not always cut that amount to zero, as the complementarity from community can still be very large and useful. (See Section A.5.)

4 The Complementarity Between Community and Police Enforcement

As tasks are either provided by the community or by outsiders, there is a sense in which community and market are substitutes: an increase in q necessarily decreases $1 - q$ on a one-for-one basis. However, when it comes to enforcement and incentive constraints, there is a complementarity, which is why we see both community and police enforcement for a range of parameter values. This holds for a range of costs for which using community enhances incentive constraints sufficiently to lower overall costs of policing enough to overcome the added cost of community provision of tasks.

Although we have been discussing this complementarity between community and police enforcement, we have not formally proven that there exists a true complementarity in terms of the usual definition of supermodularity. Here we are explicit about that complementarity.

Let $\Pi(\phi, q)$ be the expected welfare associated with the best equilibrium at given levels of (ϕ, q). Thus, $\Pi(\phi, q)$ captures the payoffs from an equilibrium q can associated cost of policing at level ϕ if q is an equilibrium, and otherwise it presumes autarky in community and/or market if the corresponding incentive constraint is not met at (ϕ, q).

We normalize by subtracting the value of autarky and we omit notation for all the primitive parameters of the setting, which are held fixed in the analysis below.

In particular,

$$\Pi(\phi, q) = \begin{cases} -C(\phi, q) & \text{if neither } IC^{com} \text{ nor } IC^{out*} \text{ is satisfied,} \\ q(t_s - t_c) - C(\phi, q) & \text{if } IC^{com} \text{ but not } IC^{out} \text{ is satisfied,} \\ (1-q)(t_s - t_o) - C(\phi, q) & \text{if only } IC^{out*} \text{ is satisfied (as if } \psi = 0\text{),} \\ q(t_s - t_c) + (1-q)(t_s - t_o) - C(\phi, q) & \text{if both } IC^{com} \text{ and } IC^{out} \text{ are satisfied.} \end{cases}$$

If the community incentive constraint is not met, but the outside constraint is met, then it must be that the outside incentive constraint is met ignoring any community ostracism - which is indicated by the * on IC^{out*} which is the constraint that $t_o \leq \phi f$.

In order to define complementarity, we first define the standard increasing differences condition. There are *weak increasing differences* relative to some $\{(q, \phi), (q', \phi')\}$ such that $q' < q, \phi' < \phi$ if

$$\Pi(\phi, q) - \Pi(\phi', q) \geq \Pi(\phi, q') - \Pi(\phi', q'); \tag{WID}$$

and there are *strict increasing differences* if

$$\Pi(\phi, q) - \Pi(\phi', q) > \Pi(\phi, q') - \Pi(\phi', q'). \tag{SID}$$

We say that community and government policing are *complements* at (q_0, ϕ_0) if:

- weak increasing differences holds for every $\{(q_0, \phi_0), (q', \phi')\}$ such that $q' < q_0, \phi' < \phi_0$, and $\{(q, \phi), (q_0, \phi_0)\}$ such that $q > q_0, \phi > \phi_0$, and
- for every neighborhood of (q_0, ϕ_0), strict increasing differences holds for some $\{(q_0, \phi_0), (q', \phi')\}$ such that $q' < q_0, \phi' < \phi_0$, or some $\{(q, \phi), (q_0, \phi_0)\}$ such that $q > q_0, \phi > \phi_0$, within that neighborhood.

Thus, complementarity requires weak inequalities for all monotone comparisons about the point (q_0, ϕ_0), and strict inequalities for some monotone comparisons about the point (q_0, ϕ_0) (including arbitrarily close comparisons).

Thus, the definition of complements is that using more policing becomes (strictly) more effective at higher rates of q.

Whether community and policing are complements or not depends on the actual values of (q, ϕ)'s. In particular, consider two points (q, ϕ) and (q', ϕ'): if incentive constraints are already met in either case, or not met at all in either case, then increasing policing is just a waste of cost and so we won't expect a strict difference unless a complementarity is built into the cost function. Instead, the complementarity comes because of a change in incentive constraints due to the interaction between community and policing.

To make this point most clearly, consider a case in which the cost function can be written as

$$C(\phi, q) = c_0 + c_1\phi + c_2 q,$$

so that there is no inherent complementarity between ϕ and q in the cost function. The strict complementarity thus has to come from the interaction of the incentive constraints. We state the following proposition for this form of cost function, and prove it for a more general class of cost functions (including, for instance $C(\phi, q) = c\phi(1 - q)$) in the appendix.

PROPOSITION **3 (Complements)**

Community and policing are complements whenever they are used together in an optimal equilibrium: if (q^*, ϕ^*) *is optimal and* $0 < q^* < 1$, *then community and policing are complements at* (q^*, ϕ^*).

Moreover, community and policing are complements at (q^*, ϕ^*) *and* $0 < q^* < 1$ if and only if $\psi > 0$ *and* IC^{out*} *is binding and* IC^{com} *holds at* (q^*, ϕ^*).

Proposition 3 states that community and policing are complements whenever the they are both active at an optimum. Recall from Proposition 1, a necessary and sufficient condition for some interior $q^*, \phi^* \in (0, 1)$ to be optimal is that ψ is above some minimal level, so that when an agent is caught by the police for not doing a task for an outsider, that agent's own community learns that fact with a high enough probability to induce some nontrivial cost of ostracism on the agent. This is seen in Figure 13. The intuition is that having more community interaction makes policing more effective as the cost of being caught is higher due to the community reaction of ostracizing criminals. In this case, policing gains an extra impact since it results not only in a fine but also in a loss of community interaction. Thus, the impact of policing on profits increases with more community interaction.

We remark that this suggests that the most effective policing is combined with active advertising of arrests. The police by informing the public of all arrests in a highly visible forum increases incentives.

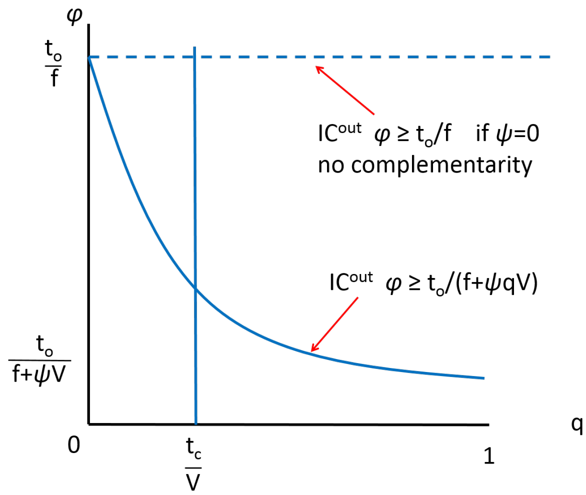


Figure 13: The complementarity comes from ψ: the chance that people in the community learn of an arrest and then ostracize. Without that effect, there is no complementarity and both incentive constraints are constants - and then the optimal equilibrium is either all police or all community.

Note that the complementarity does *not* mean that more policing is used as community interaction increases - in fact the opposite will typically be true as when policing becomes more effective then less of it is needed to enforce contracts. The complementarity is in the effectiveness of policing (the increasing differences), and does not imply a higher optimal level. The incentive constraint for work outside the community will always be binding whenever it is being used at an optimum - as without any policing there would not be any incentive to abide by a contract, and policing does not affect internal community incentives.

5 Religion and Supernatural Punishment

An important aspect of some religions that reach beyond community comes in two forms. One is that they invoke supernatural gods who punish bad behaviors. Another is that a person can be conditioned to feel guilt for bad behaviors.

Supernatural punishment and/or feeling guilty for bad behaviors can be found in most major religions in various forms. For instance, Christianity, Islam, and Judaism are relatively explicit regarding punishments for sins. Hinduism and several branches of Buddhism emphasize rewards and/or punishments through reincarnation and rebirth. Chinese traditional religion emphasizes moral reciprocity ("bao ying") and also the veneration of ancestors in not having them feel shamed because of the offsprings' misbehaviors. Such beliefs in ancestors and ancestral gods are shared by many local religions that exist throughout the developing world.

Of course, guilt can also be conditioned in ways other than via "religion". For our purposes, it does not matter exactly where this extra cost of cheating comes from, and we refer to it as "religion" for convenience, but it can be any conditioned response. Regardless of the mechanism, this results in an extra cost of not reciprocating or abiding by an agreed transaction.

We model this as an extra guilt cost or anticipated supernatural punishment, $S \geq 0$, that a person faces when they do not complete a task. The case of $S = 0$ is the model up to now.

Getting people to fear this punishment involves some indoctrination - people must be taught what is wrong and come to believe that they should feel guilt and/or will be punished with a bad future in life or the afterlife. This comes at a cost $K > 0$ that is an amount of time that it takes to be indoctrinated, etc., and is reflected in society's welfare calculation.

The new versions of the incentive constraints are:

$$t_c \leq S + \frac{\delta q(t_s - t_c)}{1-\delta}, \tag{IC^{comS}}$$

$$t_o \leq S + \phi f + \phi\psi\frac{\delta q(t_s - t_c)}{1-\delta} \tag{IC^{outS}}$$

Including the cost of "religion", the welfare optimization problem becomes:

$$\min_{\phi,q\in[0,1]^2,sign(S)} q(t_c - t_o) + c\phi + Ksign(S)$$

$$s.t. \quad q\left(S + \frac{\delta q(t_s - t_c)}{1-\delta} - t_c\right) \geq 0,$$

$$(1-q)\left(S + \phi f + \phi\psi\frac{\delta q(t_s - t_c)}{1-\delta} - t_o\right) \geq 0.$$

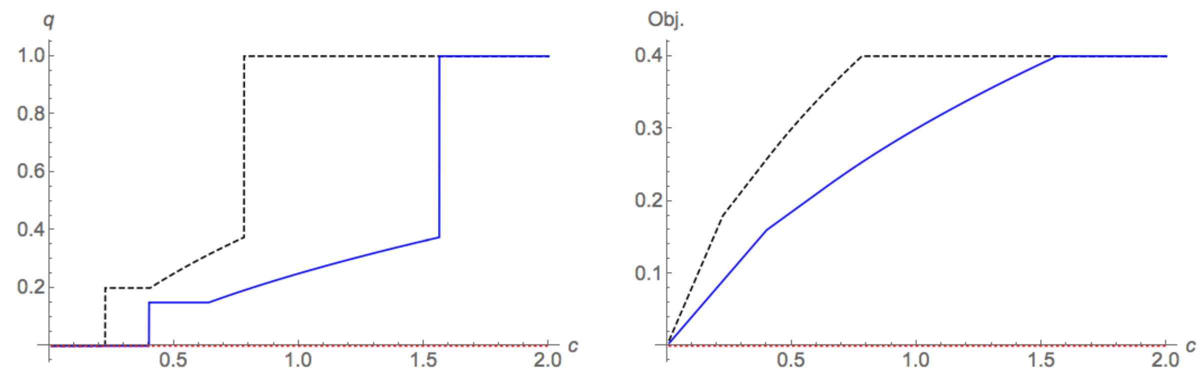
Here, just as with fines, we take the level of the anticipated punishment S as exogenous (e.g., "eye-for-an-eye"), and only examine the choice of whether society is better or worse off by having a religion.

5.1 Religion, Supernatural Punishment, and Shifting Complementarities

To illustrate how the optimal mix of government and community changes once we add supernatural punishment, we begin by revisiting the example from Section 3.4.1. We keep the base parameters the same as in Example 3.4.1, but we add in various levels of supernatural punishment.

We start with the case in which $K = 0$, to see how that changes the mix and later we add in a positive cost of indoctrination.

The new structure of the optimal equilibrium as a function of the cost of policing is pictured in Figure 14.



(a) The fraction of Community Task Provision (q) (b) Overall Costs (Opposite of Welfare: $c\phi + q(t_c - t_o) + sign(S)K$)

Figure 14: Notes: Dashed: S = 0 (no supernatural punishment, i.e. Example 3.4.1), Blue: S = 0.2, Red dotted: S = 0.4. $K = 0$, other parameters are the same as in Example 3.4.1.

The extreme at which $S = 0.4 = t_o$ (the red dotted line) is the benchmark for which (IC^{out}) never binds. In this case, the supernatural punishment is so effective that every task can be completed outside without any policing, and so all tasks are done outside with full compliance and no enforcement costs.

The less trivial cases are for $S < 0.4$. We picture the case of $S = 0.2$ as a representative situation. The effects are clear. First, a supernatural punishment makes the outside incentive constraint easier to satisfy, as policing is bolstered by a cost of guilt or afterlife-punishment. This leads to a larger region of enforcement costs for which there is no community but only policing. Community is only used after a higher threshold of costs. Second, the more interesting change is that once community is used there is a larger range of costs for which there is a complementarity between community and policing. Religion makes both incentive constraints easier to satisfy, and in particular, and then makes community a more effective complement to policing - so that it is used for a larger range of parameters.

Thus, supernatural punishment makes both community and outside enforcement more effective, and shifts and enlarges the range of costs of policing for which community is a useful complement.

Next we consider how things change when 'religion' comes with a cost.

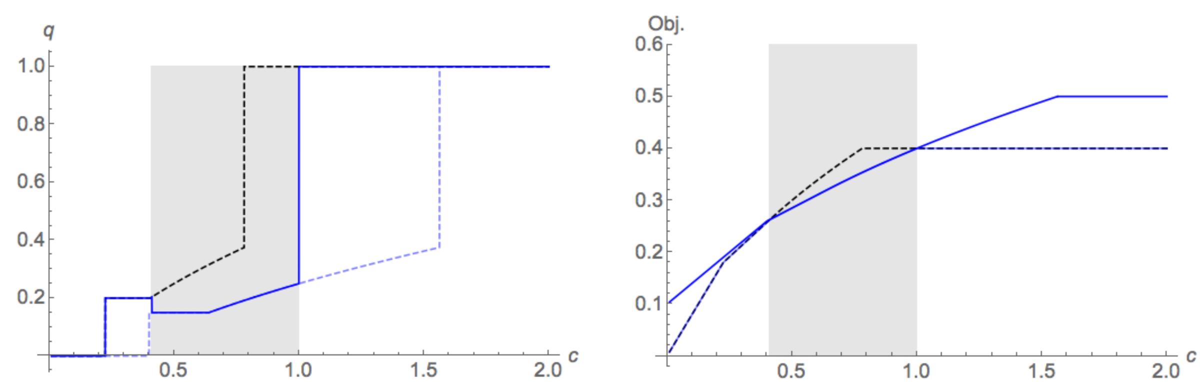
5.2 Religion, Costly Supernatural Punishment, and Shifting Complementarities

We now extend the example from Section 5.1 to include positive costs of maintaining a religion $K = 0.1$. So, there is a cost associated with any positive level of supernatural punishment $S > 0$. This involves whatever indoctrination and reinforcement that is required to have the population believe in the punishment.

We now examine when having a religion with a supernatural punishment is a part of an optimal mix. For example, if a society is such that it works entirely by community, then the supernatural punishment is redundant and does not help. In that case, it is more cost effective to have a religion that is just the community and does not involve costs associated with supernatural punishment. [8]

Therefore, for each set of parameters we first find the optimal system with (S, K), then compare it to the optimal system with zero supernatural punishment $(S, K) = (0, 0)$. When the former results in higher welfare, the supernatural punishment is active in the welfare-maximizing system.

The results with $S = 0.2$ are pictured in Figure 15 (and the case of $(S = 0.4)$ is discussed in Appendix Figure 25).



(a) The fraction of Community Task Provision (q) (b) Overall Costs (Opposite of Welfare: $c\phi + q(t_c - t_o) + sign(S)K$)

Figure 15: Notes: Black dashed: S = 0 (no supernatural punishment, i.e. Example 3.4.1), Blue: S = 0.2; the welfare-maximizing equilibrium (solid), the equilibrium assuming active supernatural punishment (dashed). The shaded area indicates a region in which supernatural punishment is active. $K = 0.1$, other parameters are the same as in Example 3.4.1.

As we see in Figure 15, supernatural punishment is active only in a middle cost range.

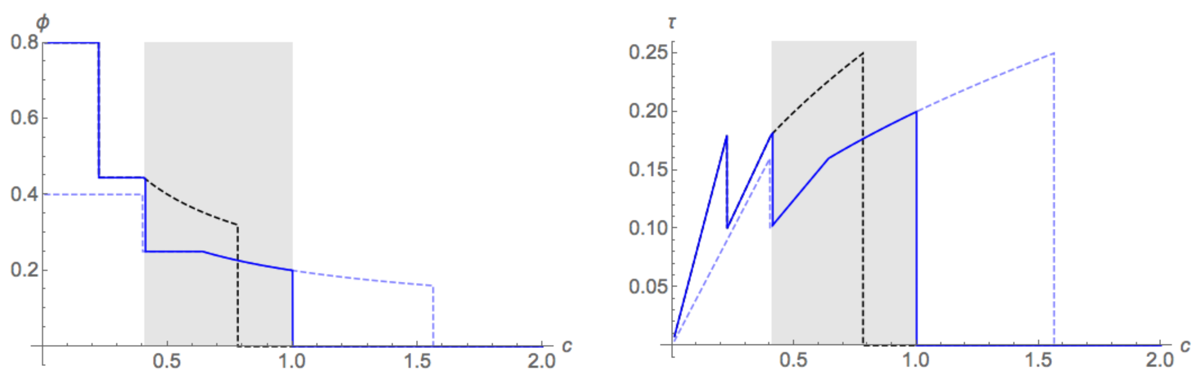
[8] This is consistent with empirical observations by Norenzayan et al. (2016); Roes and Raymond (2003). Once community becomes too large, then other enforcement becomes necessary, and so that is also a comparative static in the effectiveness of community.

For very low costs c, it is better to just use police, and once there is enough community (which often occurs for very high c), there is no additional need for the supernatural.

Once optimal religion is incorporated, the use of community becomes non-monotone, as we see in panel (a) of Figure 15. For very low costs of policing, only policing is used. As policing costs rise, community comes into play as a complement to policing. However, once policing costs continue to rise, it becomes efficient to have a religion with supernatural beliefs. Once this is in place, it then replaces some of the need for community as a complement to policing, as supernatural beliefs lower the amount of policing needed. Eventually, as policing costs continue to rise, we see community increasingly used, but at a lower level than it would be absent supernatural punishment. Finally, policing costs become so high that everything becomes community and religion is again displaced.

We prove in the appendix that as S increases, policing is used alone for a larger range of costs and then the upper bound of costs for which both policing and community are used in combination is also increased.

The optimal amount of policing follows a quite jagged pattern now, as pictured in Figure 16, because it is affected by discontinuous use of community, which is then replaced by religion, and then goes back to using community as a complement, and eventually is replaced by community.



(a) Amount of policing (ϕ) (b) Cost of policing ($c\phi$)

Figure 16: Notes: Black dashed: S = 0 (no supernatural punishment, i.e. Example 3.4.1), Blue: S = 0.2; the welfare-maximizing equilibrium (solid), the equilibrium assuming active supernatural punishment (dashed). Shaded area indicates the region in which supernatural punishment is active. $K = 0.1$, other parameters are the same as in Example 3.4.1.

It is worth noting, that religion ends up being used sometimes in combination with policing without any community, and other times when both are present. We have restricted attention to the case in which communities are self-enforcing, but if we drop that assumption, then for some parameters, religion also appears paired with community (and no policing), and in some cases with no community or policing at all.

As a last point, we note that religions can operate at different levels and have different norms about when punishments apply. For instance, under some religions it is prohibited to cheat against members of the same religion, but it is permitted to act badly against members of other religions. Viewing religion local to a community, we analyze such cases with community specific punishment in Appendix Figure 26. Community can still be valuable, and then a complement to outside enforcement, but supernatural punishments do not directly enhance policing. The gains in welfare from supernatural punishment then never exceeds 0.012 for any $S > 0$, and therefore the supernatural punishment is inactive, except for very low religion costs. This observation echoes a pattern documented in Norenzayan et al. (2016), that beliefs in “Big Gods” prevail in religions that have spread globally, or in relatively big societies; whereas small societies/religious groups seem to govern themselves with other forces (“community” in our context). The same pattern was also documented in Roes and Raymond (2003) (Fig. 1, “Society size and belief in moralising gods”, p. 131).

6 Corruption

One very basic effect of corruption is that it increases the cost of policing: the police force does less of what it is supposed to do. The corresponding analysis of that facet is just a change in the cost of policing and was included in the comparative statics in Section 3.4.

Here we examine a more subtle, but important, effect of corruption: there can be “false arrests” so that people are accused by police even if they did not commit a crime. False arrests change the interaction between policing and community as they lower the informativeness of someone being caught by the police, and so a community may no longer want to ostracize such a person. This decreases the complementarity between community and formal enforcement.

A somewhat surprising result concerning the interaction of corruption with community and its complementarity with policing, is that a change in that corruption level can lead to either more or less reliance on policing. One direction is expected: as corruption goes up, policing becomes less effective and so is used less. The second direction is the subtle one. As corruption goes up, the community becomes a less effective complement to policing, and so one has to rely on *more* policing. We explore that second effect in more detail here, as well as its interplay with the first.

We model corruption as follows. The probability ϕ of being caught now happens γ of the time when the person is innocent, and $1-\gamma$ of the time when the person is guilty. So, γ captures the level of corruption.

The effective cost of policing is now $\frac{c\phi}{1-\gamma}$, as one needs a level of policing of $\frac{\phi}{1-\gamma}$ to get a probability ϕ of being caught when one cheats.[9]

[9] Again, for ease of exposition we work with the cost function $c\phi$, but the analysis extends.

Most importantly, this changes the incentive constraints in a variety of ways. In this section, we examine the incentive constraints as if the community still ostracizes people who are caught by the police, and then come back to examine whether the community wishes to ostracize people who are arrested in the face of corruption in the next section.

First, everyone expects a lower continuation payoff, since one expects a chance of $(1-q)\phi\gamma$ of being falsely arrested in any given period and so a probability of $\psi(1-q)\phi\gamma$ of being ostracized, and then $1-\psi(1-q)\phi\gamma$ of making it through any period.

This leads to a new continuation value from community:

$$V^{corrupt} = \frac{\delta\left(1-\psi(1-q)\phi\gamma\right)(t_s - t_c)}{1-\delta\left(1-\psi(1-q)\phi\gamma\right)}. \tag{1}$$

Thus, agents face a smaller effective discount factor when calculating incentives.

Due to the change in $V^{corrupt}$, the community incentive constraints become:

$$t_c \leq qV^{corrupt}. \tag{$IC^{com,corrupt}$}$$

Next, the new incentive constraint for market interactions becomes:

$$t_o \leq \phi(1-\gamma)f + \phi\psi qV^{corrupt}. \tag{$IC^{out,corrupt}$}$$

The chance of false arrests happen on either side, and so are not included.

Thus, we see the weakening of both incentive constraints due to the lower continuation value $V^{corrupt} < V$ from future community interactions, and we also see a decreased chance of being fined for actually cheating: $\phi(1-\gamma)f$. So, corruption erodes all of the incentives.

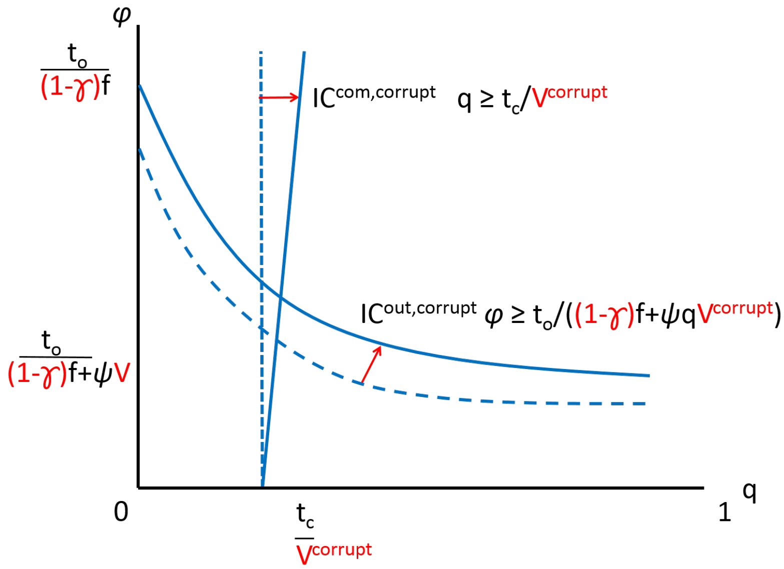
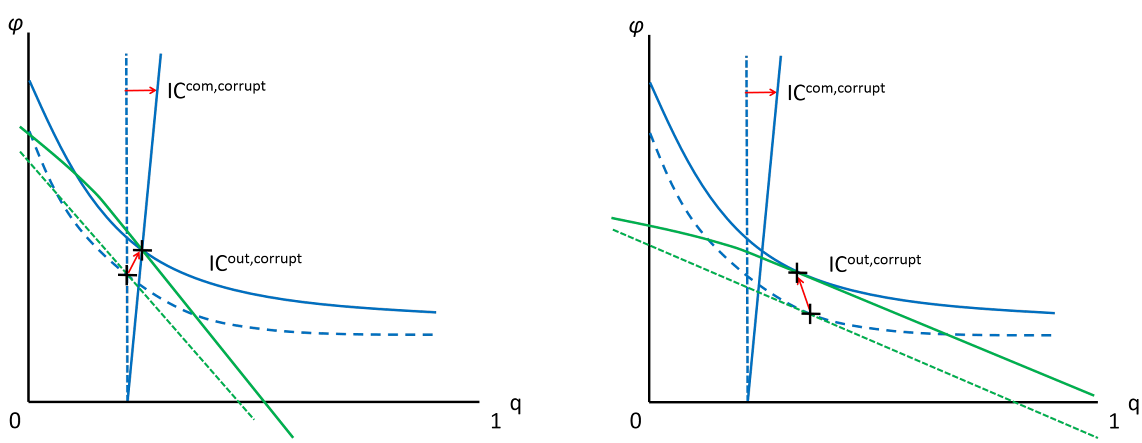


Figure 17: Both constraints get harder to satisfy with corruption. The community constraint shifts due to the lower value to future community cooperation. The outside constraint shifts due to changes in both the fine and the value of future community cooperation, and the relative way in which it shifts at different points depends on other parameters and the level of cooperation. At low levels of ϕ and high levels of q, the difference between $V^{corrupt}$ and V disappears.



(a) Community Reliance Increases

(b) Community Reliance Decreases

Figure 18: The reliance on community versus the formal sector can move in either direction as corruption increases.

In panel (a) of Figure 18, community needs to be used at a higher level to still be a complement to policing. In panel (b), community may instead decrease: it is less effective as a complement, and hence one has to rely on more policing.[10] Generally, since both modes of enforcement are weakened as is their complementarity, the best new equilibrium can be very different from the best old one.

Figure 18 does not capture all the ways in which there may be differences in community and formal market use due to corruption. For instance, another reason for the increase usage of community is that formal enforcement becomes less effective and the need for community as a complement is increased - which can be manifested as a change from no community to a (discontinuous) jump in the use of community.

Moreover, in some cases corruption can be so bad that it no longer makes sense for a community to ostracize members that have been arrested. In that case, it is as if ψ is set to 0 and there is no longer any complementarity between community and formal enforcement. This means that one then moves either entirely to the community or entirely to formal enforcement. These are always points that are considered when we optimize in any case, but they become optima for more parameter values in the face of corruption.

Some of these comparative statics can be viewed by revisiting our running example.

In looking at overall welfare, we need to account for the cost of false arrests (per capita). This is captured by $qV(q) - qV^{corrupt}(q)$, where we now make clear the dependence of the value of community on q. The characterization of the welfare-maximizing equilibrium is given by the program:

$$\min_{\phi,q\in[0,1]^2} q(t_c - t_o) + C(\phi, q) + qV(q) - qV^{corrupt}(q)$$

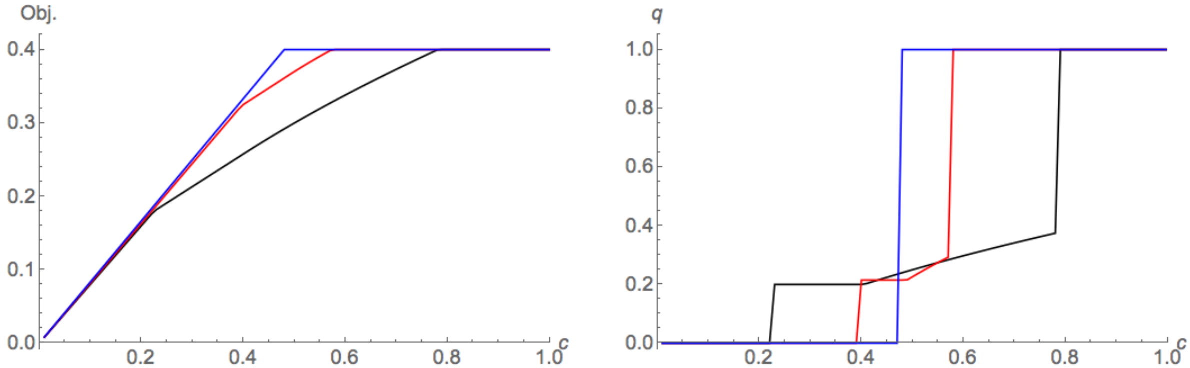
$$s.t.\ \ q\left(qV^{corrupt}(q) - t_c\right) \geq 0,$$

$$(1-q)\left(\phi(1-\gamma)f + \phi\psi qV^{corrupt}(q) - t_o\right) \geq 0.$$

An Example with Corruption

We examine several probabilities of false-arrest: $\gamma = 0$ (no corruption), 0.02, and 0.04. Other parameters are the same as in Example 3.4.1.

[10]For a numerical example of this case, consider Figure 19 (b): the level of community is lower with $\gamma = 0.02$ than the level with $\gamma = 0$, for c around 0.5.



(a) Objective function (negative of welfare)

(b) Community fraction q

Figure 19: Notes: Dashed: $\gamma = 0$ (no corruption, i.e. Example 3.4.1), Red: $\gamma = 0.02$, Blue: $\gamma = 0.04$.

As we see in Figure 19, as corruption increases, the overall welfare decreases and the region of complementarity between policing and community shrinks until it eventually disappears completely. For lower costs c, more policing is used and community disappears, while for higher costs c less policing is used and more community is used.

6.1 A Moral Refinement: A Community's Reaction to Corruption and a Discontinuity in Welfare

Once corruption enters, people are falsely arrested. The welfare maximizing equilibria that we have in the analysis above have a peculiar feature. When community and law enforcement are both being used ($0 < q < 1$), the incentive constraints are satisfied and so *all* people who are arrested are actually falsely arrested. The equilibrium requires that people ostracize anyone who is arrested, since this is required as a threat to anyone who would cheat. So there is a cost of ostracizing falsely arrested people in order to enforce incentives to avoid real cheating.

Although this all holds together as an equilibrium (in a perfect Bayesian sense), it violates a basic moral refinement. Suppose that people refuse to ostracize people whom they believe were falsely arrested. This is added as a "moral" refinement to equilibrium: it rules out certain strategies of players. In this case, it eliminates the complementarity between community and law enforcement. It creates a discontinuity: as corruption enters and false arrests appear, a community that has such a moral constraint on its actions stops ostracizing arrested individuals since they know all of arrested people are actually innocent! In equilibrium described above: a community has an incentive to ignore arrests right from the start - all arrests are false!

This refinement leads to an abrupt discontinuity in how corruption affects welfare: there is a gap in welfare that comes once corruption is introduced.

Proposition 4 *Consider a community that has a moral constraint on the strategies that it is willing to play and refuses to ostracize individuals whom they are sure are falsely arrested. If the welfare-maximizing equilibrium in the absence of corruption involves a mix of community and formal policing, then there is a discontinuous drop in welfare from any positive level of corruption.*

This sort of discontinuity may be at work in many societies in which local communities have lost faith in their police forces. There are many examples of such effects. For instance, "Black Youth Project 100" worked to undo a "permanent exclusion" policy of the New York City Housing Authority that ostracizes criminals and does not allow them to live in or visit housing projects. Activists in Chicago worked to eliminate the city's gang database, arguing that criteria for inclusion were vague.[11]

In our model, false arrest levels are extreme since incentives bind perfectly and nobody ever cheats; and so with any corruption, all arrests are false. There is no actual cheating in equilibrium as we have worked with homogeneous agents and no noise in their action. Although this is an extreme case, the discontinuity would be robust to the introduction of more noise into the model. One could introduce either heterogeneous types (some who have a greater preference to cheat) or some other noise in actions to get a positive amount of cheating and correct arrests in equilibrium. In that case, the community might tolerate a positive amount of arrests before ignoring them. Thus, the discontinuity observed in Proposition 4 would happen at a higher level of corruption. The message, however, would be the same: at some point, communities no longer react to arrests as false arrests are too large a percentage of arrests for them to tolerate, and then the complementarity between community and policing is lost and welfare drops discontinuously!

6.2 Community-Poverty Traps

Building a police force and the institutions that surround it would tend to involve an up-front investment that could be large. This is exacerbated by the fact that, as we have seen, policing is used discontinuously and so to be welfare-enhancing it should be used above a minimum scale. This makes it difficult for a society to transition from local community enforcement to having a market economy. This is especially true if the society must pay for investments out of its current consumption.

[11]For more on both of these, see "Black Lives Matter Is Democracy in Action" by Barbara Ransby, Oct 21, 2017, New York Times.

We remark that our analysis provides some insight into this sort of Community-Poverty trap. Growth and future prosperity may depend on having some market interactions, and the costs of transition can be prohibitive to a given society. Our remarks come from our three comparative statics above. Let us take them in order.

The first is that a stronger community value (high V) and a large ψ - so that a community would closely attuned to policing - both improve the complementarity of community with police enforcement. This lowers the cost of policing and the size of the force needed. Both of these increase the range of settings where a transition can be made. Thus rather than a stronger community delaying transition, it can actually help a transition given the complementarity.

The second is that religion - or strong norms of guilt or moral code - also enhance the effectiveness of policing and community. In particular, they can extend the range of policing costs at which there are greater gains from transitioning - again making the transition more attractive.

The third is that (anticipated) corruption not only makes policing less attractive, but it can also erode the complementarity resulting in a further reason not to transition.

7 Concluding Remarks

We have found a simple and powerful complementarity between exchanging informally within one's community and formally exchanging on a larger anonymous and policed market. That complementarity is affected by religion as well as corruption, as we have shown. Religion can enhance the complementarity, while corruption erodes it.

We have kept the model unencumbered by heterogeneity in tasks, people, or communities. Extending the model to include such heterogeneities could provide interesting results in several directions, if these could be done in a tractable manner.

First, introducing a heterogeneity in tasks, for instance, would provide insight into how markets grow and whether they grow from simple low-cost tasks or from more complicated high-cost tasks.

Second, introducing a heterogeneity in people's costs for providing tasks would provide insight into who specializes in which areas and could result in some equilibrium cheating. This would introduce an interesting inference problem in the face of corruption: was someone falsely arrested?

Third, introducing heterogeneity in communities, (for instance, in size) could lead to different levels of complementarity, so that only some could be trusted on market transactions.

Fourth, introducing heterogeneous and competing religions could give an idea of why religions with moral codes tend to exist: having a higher S would be advantageous. This might also introduce considerations of punishment only when dealing with someone of the same religion: one might be willing to cheat on a non-believer, if the religion allows it. Our base model could be an interesting foundation for studying the evolution and competition between religions.

Fifth, technological advances have led to many platforms on which people interact and transact, and the model could be reinterpreted and adapted to analyze the importance of linking people's identities across platforms and forcing them to use real rather than assumed identities (a growing practice on many platforms). The complementarities could be quite strong.

Sixth, one could also more explicitly model people's attitudes and reactions to corruption. When and how do people ostracize corrupt individuals? Does that affect the incentives of politicians, judges, and police?

Finally, we have assumed that each community has a fixed 'small' size. In further work it could be interesting to endogenous the size of community and relate it to various parameters in our model. For instance, larger communities might be associated with a lower t_c but also a worse ability to provide informal enforcement (e.g., as in Dixit (2003a,b)); on the other hand, people in smaller communities might know each other better and thus might be less willing to update from an arrest and less likely to ostracize and more likely to forgive than larger communities. These effects could impact the power of the complementarity with formal enforcement in interesting ways.

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A Appendix

A.1 Proofs of Propositions 1 and 2.

We first provide an analysis for the special case of $C(\phi, q) = c\phi$, as that allows for closed-form solutions. We then provide the more general proof.

A.1.1 Analysis for $C(\phi, q) = c\phi$: characterizing the optimal ϕ, q.

In this part we provide a detailed analysis for $C = c\phi$ in closed form. One could easily extend these calculations to any linear cost function $C(\phi, q) = c_0 + c_1\phi + c_2 q$, for which $c_1 > 0$, with more complicated expressions. The analysis also applies to more general cost functions, but closed form solutions may not be available.

Recall that the optimization problem is to minimize the welfare cost

$$H(\phi, q) \equiv q(t_c - t_o) + C(\phi, q)$$

subject to the two constraints.

We first analyze the optimal ϕ for different possibilities of q, and then optimize overall.

When $q = 1$ (all community), $\phi = 0$ and hence the welfare cost

$$H^{all-com} \equiv H(0, 1) = t_c - t_o$$

When $q = 0$ (all policing), binding $(IC)^{out}$ implies $\phi^{all-out} = \frac{t_o}{f}$, and hence the welfare cost is

$$H^{all-out} \equiv H(\frac{t_o}{f}, 0) = c\frac{t_o}{f}$$

There is a mixture regime in between, with $q \in (0, 1)$ such that both community and policing are active. This regime includes two situations, depending on whether $(IC)^{com}$ binds.

In particular, the mixture with a minimal community level has $(IC)^{com}$ and $(IC)^{out}$ both binding. That implies that $q = \frac{t_c}{V} = \frac{(1-\delta)t_c}{\delta(t_s - t_c)}$ and $\phi = \frac{t_o}{f+\psi t_c}$. Therefore the welfare cost is

$$H^{both-bind} \equiv H(\frac{t_o}{f+\psi t_c}, \frac{t_c}{V}) = c\frac{t_o}{f+\psi t_c} + \frac{(t_c - t_o)t_c}{V}.$$

If the optimal q is above the level $q = \frac{t_c}{V}$, then only $(IC)^{out}$ binds. In that case, minimizing H subject to $(IC)^{out}$, has a solution (local minimizer)

$$(\phi^{local}, q^{local}) = \left(\sqrt{\frac{(t_c - t_o)t_o}{c\psi V}}, \sqrt{\frac{ct_o}{(t_c - t_o)\psi V}} - \frac{f}{\psi V}\right).$$

The corresponding (local minimal) welfare cost is

$$H^{local} \equiv H(\phi^{local}, q^{local}) = 2\sqrt{\frac{ct_o(t_c - t_o)}{\psi V}} - \frac{f(t_c - t_o)}{\psi V}.$$

From this, we can fully characterize the mixture regime:

$$H^{mix} = \begin{cases} H^{both-bind} & \text{if } q^{local} \leq \frac{t_c}{V} \qquad \text{(minimal community level)} \\ H^{local} & \text{if } q^{local} > \frac{t_c}{V} \qquad \text{(high community level)} \end{cases}$$

q^{mix} and ϕ^{mix} are defined in a similar way. Intuitively, when $q^{local} \leq \frac{t_c}{V}$, $(IC)^{com}$ binds: $q = \frac{t_c}{V}$ and the mixture regime is described by low community mixture in which both (IC)'s bind; whereas when $q^{local} > \frac{t_c}{V}$, $(IC)^{com}$ is slack and the mixture regime adopts the local optimum.

Finally, the (globally) optimal regime is one that minimizes the welfare cost.

$$H^* = \min\left(H^{all-com}, H^{mix}, H^{all-out}\right)$$

.

A.1.2 Proofs of Propositions 1 and 2 for the more general cost function.

Recall that Propositions 1 and 2 are stated for

$$C(\phi, q) = cP(\phi, q),$$

in which $c > 0$ is a scalar, P is increasing in ϕ, non-increasing in q, and quasi-convex in (ϕ, q).

($H^{all-com}, H^{mix}, H^{all-out}$ are defined similarly to the analysis for $C = c\phi$ (in A.1), and the globally optimal welfare cost is still the smallest among the three, although closed-form solutions are no longer available for this more general case.

Proof of Proposition 1

Recall that $H^{all-com} \equiv H(1,0) = t_c - t_o - cP(1,0)$ and $H^{all-out} \equiv H(0, \phi^{all-out}) = -cP(0, t_o/f)$, and so

$$H^{all-com} - H^{all-out} = t_c - t_o + c\left[P(0, t_o/f) - P(1,0)\right].$$

Note that given the quasi-convexity of the cost function, and the strict convexity of the set of q, ϕ that satisfy IC^{out} (for which $q > 0$) given $\psi > 0$, it follows that there exists a unique $q^{mix}(c) \in (0,1]$, $\phi^{mix}(c) \in (0, t_o/f)$ for every $c > 0$ which minimizes the objective function subject to both IC^{in} and IC^{out} both holding (which requires $\phi > 0$).[12] Given the differentiability of C for positive ϕ, and that $C = cP$, it follows from the Envelope Theorem (e.g., see Milgrom and Segal (2002)) that H^{mix} is differentiable in c at maximizing points.

First, we consider how the H's change with c.

$$\frac{\mathbf{d}}{\mathbf{d}c} H^{all-com} = -P(0,1), \quad \text{and} \quad \frac{\mathbf{d}}{\mathbf{d}c} H^{all-out} = -P(t_o/f, 0),$$

and it follows from the Envelope Theorem that

$$\frac{\mathbf{d}}{\mathbf{d}c} H^{mix} = \frac{\partial}{\partial c} H^{mix} = -P(\phi^{mix}(c), q^{mix}(c)).$$

From the monotonicity properties of P (and the fact that $q^{mix}(c) > 0$, $\phi^{mix}(c) \in (0, t_o/f)$) that $P(t_o/f, 0) > P(\phi^{mix}(c), q^{mix}(c)) > P(0,1)$ and hence

$$\frac{\mathbf{d}}{\mathbf{d}c}(H^{mix} - H^{all-com}) > 0, \text{ and } \frac{\mathbf{d}}{\mathbf{d}c}(H^{mix} - H^{all-out}) < 0, \quad \forall c > 0. \tag{2}$$

Moreover, it is easy to see that $H^{all-com}$ is the smallest (among the three) for c big enough, while $H^{all-out}$ is the smallest for $c = 0$. Therefore, there exists two thresholds c^{out} and c^{com}, such that

- $H^{mix} - H^{all-com} \geq 0$ whenever $c \geq c^{com}$
- $H^{mix} - H^{all-out} \geq 0$ whenever $c \leq c^{out}$.

Now we consider how H's move in ψ.

[12] Note that the solution to this restricted program where we require both constraints to hold can involve $q = 1$, but that would always be dominated by the all community solution.

Recall that ψ only enters the problem through IC^{out}:

$$t_o \leq \phi f + \phi\psi q V, \qquad (IC^{out})$$

and a larger ψ increases the right hand side of IC^{out} whenever $q > 0$.

Therefore, the welfare cost $H^{all-com}$ and $H^{all-out}$ are both constant in ψ, while H^{mix} increases in ψ. Therefore

Observation: $H^{mix} - H^{all-com}$ and $H^{mix} - H^{all-out}$ both increase in ψ.

It follows from the above observation, condition 2 and the definition of c^{out} and c^{com} that c^{com} increases in ψ, and c^{out} decreases in ψ.

Now we are ready to prove the other statements in the proposition:

When $\psi = 0$, we must have $c^{com} < c^{out}$, because the mixture regime is then never optimal: in this case IC^{out} does not depend on q, and hence any (q, ϕ) with $0 < q < 1$ is strictly dominated by $(0, \phi)$, that is an all-policing regime with the same level of ϕ.

This observation, together with the monotonicity of the two thresholds in ψ, implies that there exists some $\bar{\psi}$ such that $c^{com} < c^{out}$ if $\psi < \bar{\psi}$, and $c^{com} > c^{out}$ if $\psi > \bar{\psi}$. Notice that it is possible that $\bar{\psi} = \infty$. This $\bar{\psi}$ is the threshold that divides the two cases stated in the proposition.

For part 1, $\psi < \bar{\psi}$ implies $c^{com} < c^{out}$ and so the mixture regime is never optimal. That is, the optimal regime is either all-community or all-policing.

Recall $H^{all-com} \equiv H(0,1) = t_c - t_o - cP(0,1)$ and $H^{all-out} \equiv H(\phi^{all-out}, 0) = -cP(t_o/f, 0)$, so

$$H^{all-com} - H^{all-out} = t_c - t_o + c\left[P(t_o/f, 0) - P(0,1)\right]$$

Therefore, $H^{all-com} > H^{all-out}$ iff $c > c^* \equiv \frac{t_c - t_o}{P(t_o/f,0) - P(0,1)} > 0$.

For part 2, $\psi > \bar{\psi}$ implies $c^{com} > c^{out}$ and so the mixture regime is optimal for $c \in (c^{out}, c^{com})$.

Finally, the characterization of the two sub-cases of the mixture regime(s) follows directly from the comparative statics of q, ϕ in c, which appears in the proof of Proposition 2. ∎

Proof of Proposition 2

Again we work with the welfare cost H, which moves in opposite directions to welfare Π.

Proposition 1 and its proof imply the statements in this Proposition *across* regimes, i.e., when the increase in c results in any change in the optimal regime. What is left is to show that the results hold also *within* each regime.

For the comparative statics regarding the welfare, it simply follows Envelope theorem that

$$\frac{\mathbf{d}H}{\mathbf{d}c} = -P(\phi(c), q(c)) \leq 0, \quad \forall c$$

, in which strict inequality holds for any $P(\phi(c), q(c)) > 0$, which necessarily occurs when $\phi(c) > 0$.

Now we show the second part of comparative statics, regarding ϕ and q.

In the *all-community* regime, both the welfare cost is $t_c - t_o$, $q = 1$ and $\phi = 0$ are all constant in c, so the stated results are trivial.

In the *all-policing*, both q and ϕ are constant in c, and hence the welfare cost strictly increases in c.

Finally, in the *mixture* regimes, IC^{out} is binding and this implies that ϕ can be written as a strictly decreasing function of q:

$$\phi(q) = \frac{t_o}{f + \psi q V}$$

and hence the optimization problem becomes

$$\max_{q \geq t_c/V} -H(q; c) \equiv -q(t_c - t_o) - cP(q, \phi(q))$$

It follows from P decreases in q that $H(q; c)$ is super-modular in (c, q), and therefore the optimal q increases in c, and so the optimal ϕ decreases in c. ∎

A.2 Proof of Complementarity: Proposition 3

We provide some more general results, to which Proposition 3 is a corollary. We begin with a characterization of when strict increasing differences is satisfied.

Lemma **1 (Strictly increasing differences)** *Consider a cost function $C(\phi, q) = c_0 + c_1\phi + c_2 q$, for some scalars, for which $c_1 > 0$.*

Strict increasing differences holds for some $\{(q, \phi), (q', \phi')\}$ such that $q' < q, \phi' < \phi$ if and only if *$\psi > 0$, $q \in (0, 1)$, and the community and outside incentive constraints are satisfied at (q, ϕ), and IC^{out} fails at each of the other three combinations (or IC^{out*} fails in case that q' also fails to satisfy IC^{com}).*

More generally, if $C(\phi, q)$ is such that $-C(\phi, q)$ satisfies weak increasing differences (relative to any $q' < q, \phi' < \phi$), then strict increasing differences holds for some $\{(q, \phi), (q', \phi')\}$ such that $q' < q, \phi' < \phi$ if $\psi > 0$, $q \in (0, 1)$, and the community and outside incentive constraints are satisfied at (q, ϕ), and IC^{out} fails at each of the other three combinations (or IC^{out*} fails in case that q' also fails to satisfy IC^{com}).

Proof of Lemma 1

Recall that the incentive constraints are:

$$t_c \leq qV = \frac{\delta q(t_s - t_c)}{1-\delta}, \tag{IC^{com}}$$

and

$$t_o \leq \phi f + \phi\psi qV. \tag{IC^{out}}$$

Also,

$$t_o \leq \phi f, \tag{IC^{out*}}$$

is the outside incentive constraint that covers the case in which IC^{com} fails to hold (which also means that $q < 1$).

It follows directly that IC^{com} is independent of ϕ. Therefore, from the definition of $\Pi(\phi, q)$ it follows that there are two possible cases for $\Pi(\phi, q) - \Pi(\phi', q)$, depending on the incentive constraints.

Case 1:

$$\Pi(\phi, q) - \Pi(\phi', q) = -c_1(\phi - \phi'),$$

if

(i) IC^{com} holds for q and IC^{out} holds at both q, ϕ and q, ϕ',

(ii) IC^{com} holds for q and IC^{out} fails at both q, ϕ and q, ϕ',

(iii) IC^{com} fails for q and IC^{out*} holds at both ϕ and ϕ', or

(iv) IC^{com} fails for q and IC^{out*} fails at both ϕ and ϕ'.

Case 2 (only possible when $\psi > 0$):

$$\Pi(\phi, q) - \Pi(\phi', q) = -c_1(\phi - \phi') + (1-q)(t_s - t_o).$$

if either

(v) IC^{com} holds for q and IC^{out} holds at q, ϕ but not at q, ϕ', or

(vi) IC^{com} fails for q and IC^{out*} holds at ϕ but not at ϕ'.

Therefore, the only way to satisfy (SID) is for $0 \leq q' < q < 1$ and

$$\Pi(\phi, q) - \Pi(\phi', q) = -c_1(\phi - \phi') + (1-q)(t_s - t_o)$$

while

$$\Pi(\phi, q') - \Pi(\phi', q') = -c_1(\phi - \phi')$$

This requires that one of (v)-(vi) applies for q and one of (i)-(iv) for q'.

Given that $q > q'$ and $\phi > \phi'$, some possible combinations are ruled out. For instance (i) at q' implies that it holds for q too, and (vi) at q implies that (vi) holds for q' too.

Thus, we are left for one of (ii)-(iv) at q' and (v) at q. Note that (v) rules out (iii). Thus, we are left with (ii) or (iv) at q' and (v) at q.

Note also that having (v) and either (ii) or (iv) requires that $\psi > 0$, since it means that the outside constraints must depend on the level of q.

Thus, we can conclude that (SID) applies *if and only if* IC^{com} holds for q and IC^{out} holds at q, ϕ but not at q, ϕ'; while either IC^{com} fails for q' and IC^{out*} fails at both ϕ and ϕ', or IC^{com} holds for q' and IC^{out} fails at both ϕ and ϕ'; and $\psi > 0$.

To see the proof of the second statement, note that as a direct extension of the above proof, under the conditions

$$\Pi(\phi, q) - \Pi(\phi', q) = -(C(\phi, q) - C(\phi', q)) + (1 - q)(t_s - t_o)$$

while

$$\Pi(\phi, q') - \Pi(\phi', q') = -(C(\phi, q') - C(\phi', q')).$$

By the weak increasing differences condition of $-C$, it then follows that

$$\Pi(\phi, q) - \Pi(\phi', q) > \Pi(\phi, q') - \Pi(\phi', q'),$$

as claimed. ∎

Proposition 3 is a corollary of the following.

PROPOSITION **5 (Complements)**

Consider a cost function such that $-C(\phi, q)$ satisfies weak increasing differences (relative to any $q' < q, \phi' < \phi$). Then

1) *Community and policing are complements whenever they are used together in an optimal equilibrium: if (q^*, ϕ^*) is optimal and $0 < q^* < 1$, then community and policing are complements at (q^*, ϕ^*).*

2) *Moreover, community and policing are complements at (q^*, ϕ^*) for which $0 < q^* < 1$* if *$\psi > 0$ and IC^{out*} is binding and IC^{com} holds at (q^*, ϕ^*).*

3) *In addition, if $C(\phi, q) = c_0 + c_1\phi + c_2 q$, for some scalars, for which $c_1 > 0$, then community and policing are complements at (q^*, ϕ^*) for which $0 < q^* < 1$* if and only if *$\psi > 0$ and IC^{out*} is binding and IC^{com} holds at (q^*, ϕ^*).*

Proof of Proposition 5 We first show statement 2), then 3), then 1).

First we show statement 2)**.** Consider any q^*, ϕ^* that are optimal with $q^* \in (0,1)$. We show a stronger result:

a) for every (q, ϕ) such that $q > q^*, \phi > \phi^*$, (WID) holds, and

b) for every (q, ϕ) such that $q < q^*, \phi < \phi^*$, (SID) holds.

(q^*, ϕ^*) being optimal implies that IC^{out} must be binding and IC^{com} must hold. Therefore, both IC^{out} and IC^{com} must also hold for any $q > q^*, \phi > \phi^*$. It then follows that

$$\Pi(\phi, q) - \Pi(\phi^*, q) = C(\phi^*, q) - C(\phi, q) \geq C(\phi^*, q^*) - C(\phi, q^*) = \Pi(\phi, q^*) - \Pi(\phi^*, q^*), \ \ \forall q > q^*, \phi > \phi^*,$$

in which "$\geq$" follows the assumption that $-C(\phi, q)$ has weak increasing differences.

So we have proved part *a*).

For part *b*), consider any (q, ϕ) such that $q < q^*, \phi < \phi^*$. We first show that (v) is satisfied relative to q^* and any $\phi < \phi^*$: it follows that IC^{com} holds for q^* and IC^{out} holds at (q^*, ϕ^*) but not at (q^*, ϕ) (since IC^{out} is binding at (q^*, ϕ^*)).

Now we show (ii) or (iv) is satisfied relative to q $(< q^*)$ and any $\phi < \phi^*$. If IC^{com} holds for q, then since IC^{out} was binding at q^*, ϕ^* and $\psi > 0$ it must fail at q, ϕ^* and q, ϕ. If IC^{com} fails for q', then since $\psi > 0$ and IC^{out} is binding at q^*, ϕ^*, it must be that IC^{out*} (a stronger constraint) fails at both q', ϕ^* and q', ϕ'.

As a result, it follows from the proof of Lemma 1 that

$$\begin{aligned}
& [\Pi(\phi^*, q^*) - \Pi(\phi, q^*)] - [\Pi(\phi^*, q) - \Pi(\phi, q)] \\
= & -(C(\phi^*, q^*) - C(\phi, q^*) + (C(\phi^*, q) - C(\phi, q)) + (1-q)(t_s - t_o) \\
\geq & \ (1-q)(t_s - t_o) \\
> & \ 0
\end{aligned}$$

Again "$\geq$" follows $-C(\phi, q)$ having weak increasing differences. So, we have shown part *b*) and therefore completed the proof of 2)

Next, we show statement 3). First observe that the "if" part is a corollary of 2), because $C(\phi, q) = c_0 + c_1\phi + c_2 q$ satisfies weak increasing differences. What is left is the "only if" part; that is, complementarity does not hold at any (q_0, ϕ_0) such that

c) IC^{com} fails, *or*

d) IC^{com} holds, but IC^{out} fails, *or*

e) IC^{com} and IC^{out} both hold, but IC^{out} is slack.

In any the above cases, part 2 of the definition of complementarity fails. We apply the proof of Lemma 1 to show these in turn.

For c), there exists some small enough neighborhood of (q_0, ϕ_0) such that IC^{com} also fails for every (q, ϕ) in the neighborhood. So IC^{out*} shall be considered and it is independent of q. Therefore, the same case ((iii), (iv), or (vi)) must apply to both q and q_0, and hence (SID) fails.

For d), IC^{out} fails for (q_0, ϕ_0) implies that there exists some small enough neighborhood of (q_0, ϕ_0) such that IC^{out} also fails for every (q, ϕ) in the neighborhood. Moreover, in the same neighborhood, in case $q < q_0$ and IC^{com} fails for q, then IC^{out*} would also fail for $\phi < \phi_0$ since it is a stronger constraint than IC^{out}. As a result, (ii) or (iv) applies to q and q_0 (could be different). In either case (SID) fails.

For e), there exists some small enough neighborhood of (q_0, ϕ_0), such that every (q, ϕ)in the neighborhood IC^{out} holds for both $(\bar{q}, \phi_0)$ and $(\bar{q}, \phi)$ in which $\bar{q} \equiv \max(q_0, q)$. Therefore (i) or (iii) holds for $\bar{q}$ which implies (SID) holds.

So, we have completed the proof of the "only if" part.

Finally, note that statement 1) **is a corollary to statement** 2): for (q^*, ϕ^*) to be an optimum with $q^* \in (0, 1)$, IC^{out} must be binding at (q^*, ϕ^*). Therefore the community and policing are complements at (q^*, ϕ^*). ∎

Supplementary Appendix: Additional Comparative Statics

A.3 Comparative Statics in the Discount Rate and Cost of Autarky δ, t_s

We continue our discussion of comparative statics with changes in parameters that only affect the incentive constraints, but not the welfare costs $(c\phi + q(t_c - t_o)$, so parameters other than $c, t_c, t_o)$.

We begin with δ or t_s. By changing δ or t_s, the incentive constraints shift as in Figure 20.

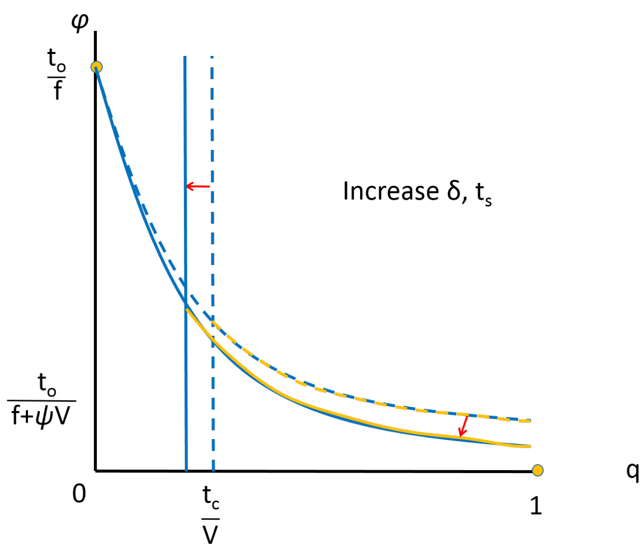
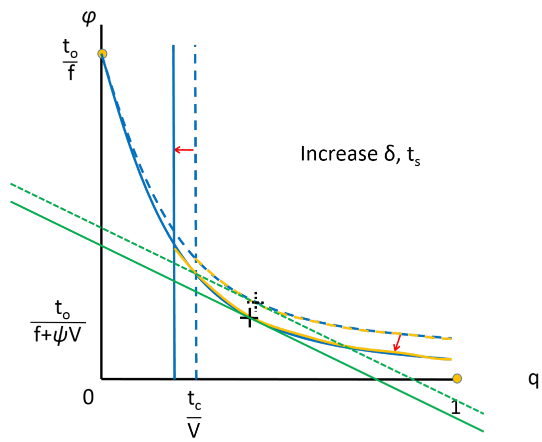


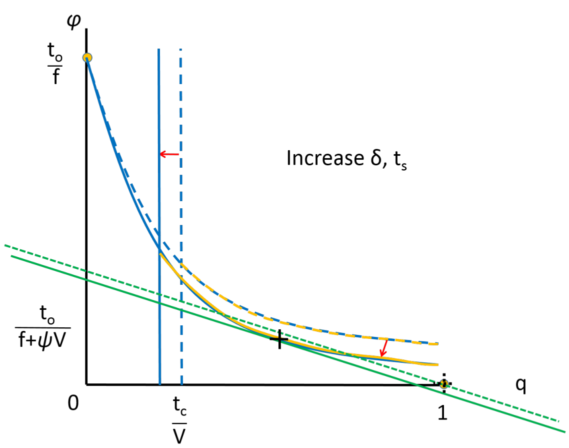
Figure 20: Comparative statics as δ and/or t_s are increased.

Depending on circumstances, this can lead to five possible changes in outcomes. Two of the possibilities is that there is no change in the welfare-maximizer. If the solution was $q = 0$ or $q = 1$, and the cost c was sufficiently large or small, then there is no change.

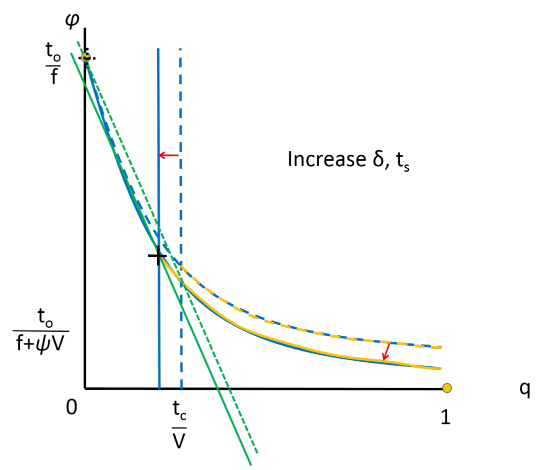
However, there are also three other possibilities as pictured in Figure 21:



(a) The initial welfare-maximizer involved interior q



(b) The initial welfare-maximizer involved all community: $q = 1$



(c) The initial welfare-maximizer involved all policing: $q = 0$

Figure 21: Comparative Statics in the discount rate and cost of autarky, δ and t_s.

Proposition 6 **(Comparative Statics in the discount rate and cost of autarky, δ and t_s)** *An increase in δ and/or t_s leads to an increase in V, and as a result:*

- *If $1 > q > 0$ then qV weakly increases, ϕ weakly decreases, and welfare strictly increases (Panel (a) of Figure 21); q strictly decreases if $f < \psi t_c$.*
- *If $q = 1$ then either there is no change (optimal regime remains the same); or the mixture regime(s) become optimal and as a result q decreases, ϕ increases and welfare strictly increases (Panel (b) of Figure 21).*
- *If $q = 0$ then either there is no change (optimal regime remains the same); or the mixture regime(s) become optimal and as a result q increases and ϕ decreases and welfare strictly increases (Panel (c) of Figure 21).*

Following any increase in V, regime change only goes from *all community* or *all policing* to *mixture*, but not the opposite. In particular, an increase in V favors the *mixture* regime with an enhanced complementarity. Therefore, as V increases, the *mixture* regime(s) become more beneficial (higher welfare) and more affordable (both incentive constraints being less restrictive).

Proof of Proposition 6

An increase in δ or t_s affects the problem only through an increase in $V \equiv \frac{\delta(t_s-t_c)}{1-\delta}$. We only need to show the comparative statics in V.

Recall that the analysis of optimal regimes are presented in Proposition 1 and Part A.1.1.

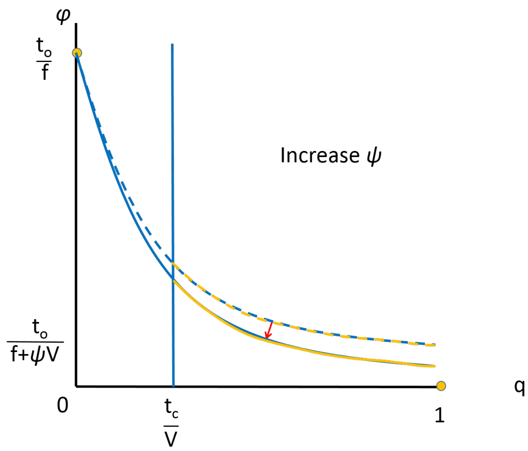
We start with $1 > q > 0$. We are in a mixture regime, with either a *high community level* or (2) a *minimal community level*: (1) If it is a *high community level*, then $q = \frac{t_c}{V}$ strictly decreases in V, $\phi = \frac{t_o}{f+\psi qV} = \frac{t_o}{f+\psi t_c}$ is a constant in V, and therefore the welfare strictly increases in V. (2) If it is a *minimal community level*, then (ϕ, q) follows the interior solutions. $\phi^{local} = \sqrt{\frac{(t_c-t_o)t_o}{c\psi V}}$ strictly decreases in V, and $q^{local} = \sqrt{\frac{ct_o}{(t_c-t_o)\psi V}} - \frac{f}{\psi V}$. $\frac{d}{dV}q^{local} = \frac{-1}{2V}\left[\sqrt{\frac{ct_o}{(t_c-t_o)\psi V}} - \frac{f}{\psi V} - \frac{f}{\psi V}\right] \leq \frac{-1}{2V}\left[\frac{t_c}{V} - \frac{f}{\psi V}\right] < 0$ if $\psi t_c < f$. In addition, the optimal regime may change from a *high community level* to a *minimal community level*, but the above comparative statics hold under such a change.

For $q = 1$ or $q = 0$, nothing changes in V unless there is a regime change. An large enough increase in V may change the optimal regime to the *mixture* (high or low community) since both (IC^{com}) and (IC^{out}) become less restrictive. When the regime change(s) happen, q, ϕ and the welfare change as stated by construction of the optimal regimes.

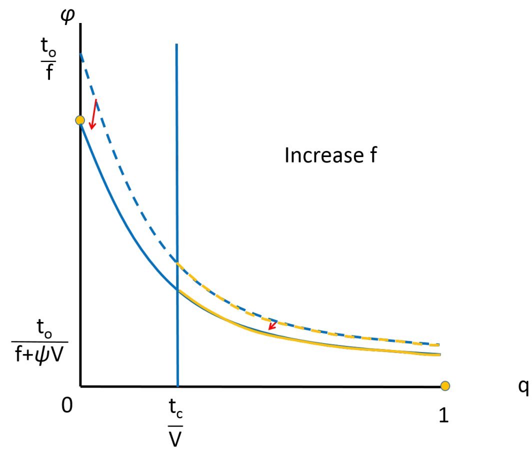
Finally, we notice that following any increase in V, regime change only goes from *all community* or *all policing* to *mixture*, but not the opposite. This is because an increase in V makes the *mixture* regime(s) more affordable and increases the welfare in it, but changes nothing in the two other regimes. ∎

A.4 Comparative Statics in the Fines and Chance of an Arrest Being Known to the Community f, ψ

Changes in ψ and f are similar to changes in δ, t_s except that they only change the outside incentive constraint, as pictured in Figure 22. These two cases differ slightly from each other, since changes in f also change the intercept of the outside incentive constraint, while ψ only changes the relative slope.



(a) Comparatives statics in ψ



(b) Comparatives statics in f

Figure 22: Comparatives statics in ψ, and f.

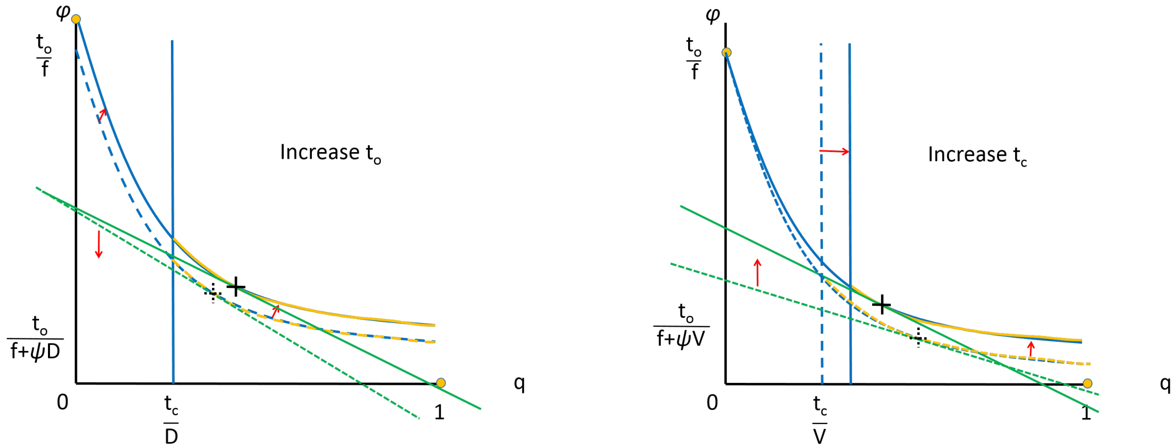
Since these are similar to the case of δ, t_s we omit a statement of the proposition.[13]

A.5 Comparative Statics in the Cost of Community and Outside Production, t_c, t_o

Changes in t_c, t_o affect both the costs of enforcement as well as the incentive constraints. Thus, these are the most complicated and ambiguous.

Given the multiplicity of possible outcomes, we omit a full statement of a proposition, but we illustrate the main effects in Figure 23 for the case in which the initial and final solutions involve interior q. The other cases are in which there is a shift to a corner solution.

[13]For f there is an extra case because of the change in intercept...



(a) Comparative statics in t_o.

(b) Comparative statics in t_c.

Figure 23: Comparatives statics in t_o, t_c.

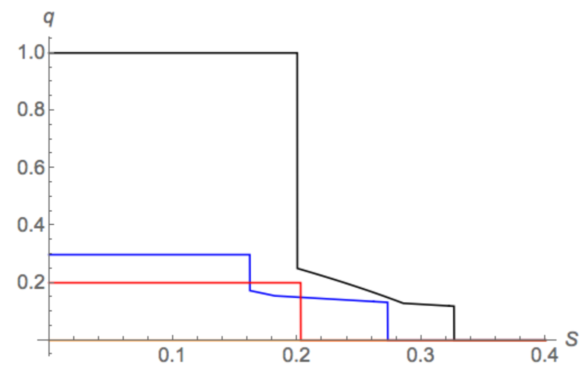
The relative gain of getting help outside, $t_c - t_o$, increases when a society industrializes, and/or during the urbanization process. This would correspond to a decrease in t_o and an increase in t_c. As illustrated in Figure 23, this would correspond to the opposite move from that pictured in panel (a) combined with the move pictured in panel (b). The main effect of such a change typically results in a lower q, which is consistent with the anecdotal evidence (e.g., Putnam (2000)) that more industrialized societies tend to use less community and more policing.

There are also some situations in which it could lead to a jump from a corner solution of all policing to minimal use of community, as the outside incentive curve shifts down - for instance with a large drop in t_o and no change in t_c. So, the overall effect can be ambiguous in some extreme cases.

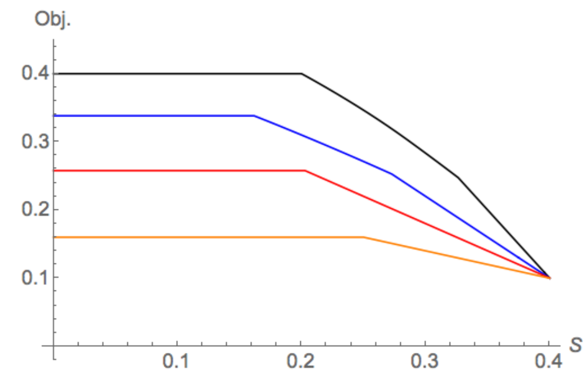
A.6 Comparative Statics in Supernatural Punishment

Proposition **7 (Comparative Statics in the Supernatural Punishment S)** *As S increases welfare weakly increases, and welfare strictly increases whenever supernatural punishment is active. Moreover, as for the cost thresholds of regime switches: c^{com} increases in S, and c^{out} also increases in S when $C = c\phi$.*

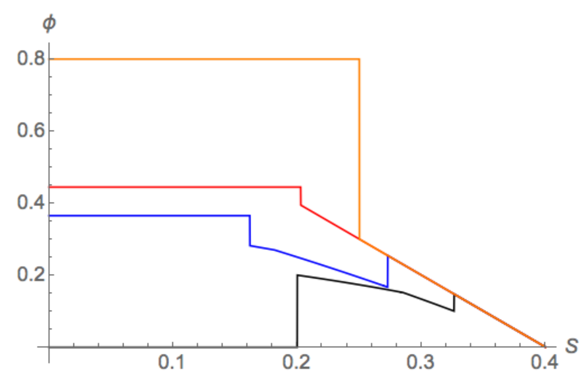
Proof of Proposition 7 An increase in S increases welfare because it relaxes both incentive constraints. In addition, when supernatural punishment is active, we have $q < 1$ and $c > 0$ and hence (IC^{out}) was binding before the increase. As a result, the increase in S brings a marginal benefit of at least $c > 0$ (in saving the cost of policing).



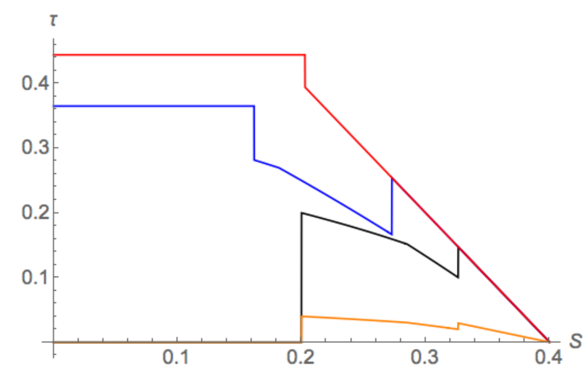
(a) The fraction of Community Task Provision (q)



(b) Overall Costs (Opposite of Welfare: $c\phi + q(t_c - t_o) + sign(S)K$)



(c) Amount of policing (ϕ)



(d) Cost of policing ($c\phi$)

Figure 24: Notes: Black: $c = 1$, Blue: $c = 0.6$, Red: $c = 0.4$, Orange: $c = 0.2$. $K = 0.1$, other parameters are the same as in Example 3.4.1.

In this case, the intersection point of the two incentive constraints is on or below the line that connects $(t_o/f, 0)$ (all-policing) and $(0, 1)$ (all-community). Hence some mixture regime that uses both community and policing becomes optimal for some levels of c.

As for the two thresholds: for c^{com} observe that H^{mix} decreases in c and decreases in S whereas $H^{all-com}$ is constant in both c and S. Thus, c^{com} – as the solution to $H^{mix} = H^{all-com}$ – must increase in S.

Finally, for c^{out}, assume $C = c\phi$. By definition c^{out} solves solves $H^{mix}(c; S) = H^{all-out}(c; S)$. Similar to the analysis A.1 (which was for $S = 0$), it follows that

$$c^{out} \equiv \left[\frac{1}{f} - \frac{1}{f + \psi t_c - \psi S}\right]^{-1} \frac{(t_c - S)}{(t_o - S)} \frac{(t_c - t_o)}{V}$$

increases in S (as both of the first two terms increase in S). ∎

Supplementary Online Appendix

A.7 More examples with costly supernatural beliefs

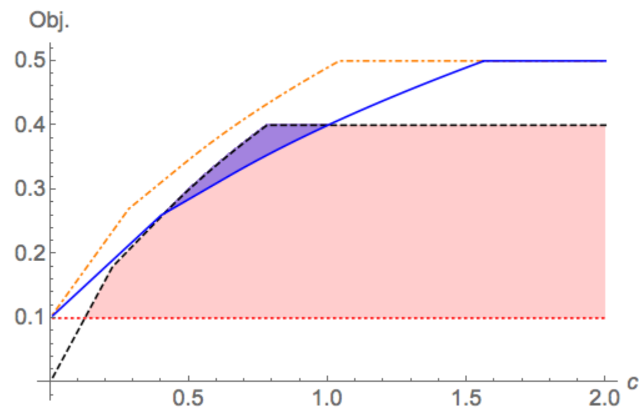


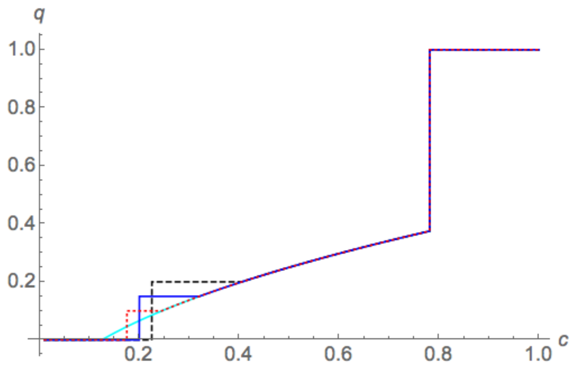
Figure 25: Notes: Objective (cost) function in the unit cost of policing c, when there is a constant cost $K = 0.15$ associated with any positive level of supernatural punishment. Note: Dashed: S = 0, Orange dotdashed: S = 0.1, Blue: S = 0.2, Red dotted: S = 0.4. Curves are the cost functions assuming active supernatural punishment. The shaded areas indicate the net amount of cost saved by supernatural punishment, when it is indeed active.

The blue curve ($S = 0.3$) was already discussed in details in Section 5.2. For some level of supernatural punishment (e.g. $S = 0.15$, the red curve), the benefit of supernatural punishment never exceeds its cost K, and in this case the supernatural punishment is never active for any c.

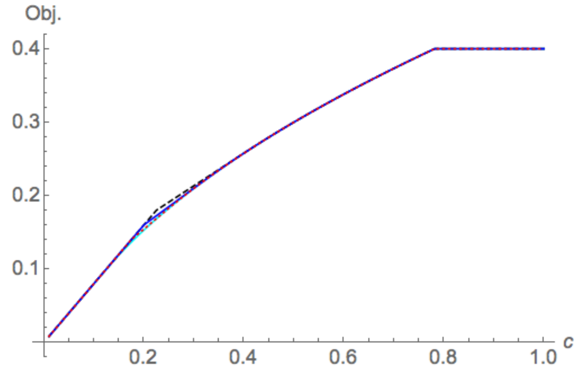
A.8 Community-specific supernatural beliefs

What if supernatural punishment in within-community interactions differs from that in outside- interactions?

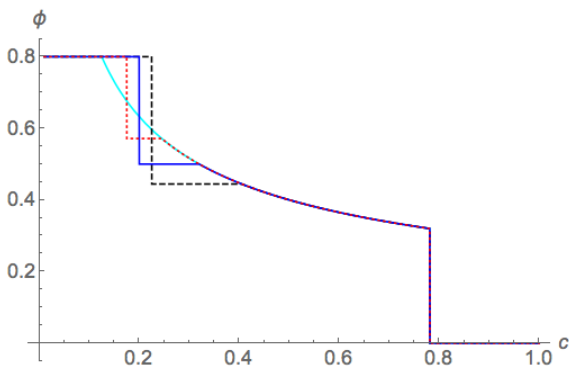
Example 1 **(Community specific supernatural punishment)** *Suppose now supernatural punishment only applies to the interactions within-community. To be specific, S appears in (IC^{comS}) but not in (IC^{out}). Parameters are the same as in Example 5.1. In particular, here we assume $K = 0$, i.e. no cost is associated with supernatural punishment.*



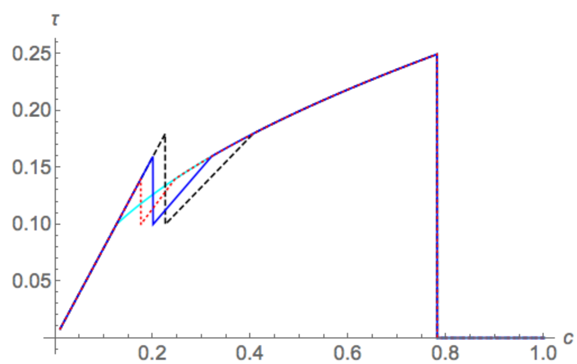
(a) Within-community-fraction q



(b) Objective function (welfare cost)



(c) Detection rate ϕ



(d) Cost of policing $\tau = c\phi$

Figure 26: Notes: Dashed: S = 0 (no supernatural punishment, i.e. Example 3.4.1), Blue: S = 0.2, Red dotted: S = 0.4, Cyan: S = 0.8. The first four levels of supernatural punishment are also considered in Example 5.1. One additional level $S = 0.8 = t_c$ is included as a benchmark case: $S \geq 0.8$ (IC^{comS}) never binds.

With the same strength of supernatural punishment as in Example 5.1, existence of supernatural punishment has little impact to the welfare (less than 0.01167 *in terms of the reduction in welfare cost, evaluated at* $K = 0$*). Community-specific supernatural punishment slightly alters the optimal system only when* (IC^{com}) *is binding.*