

The Crime of Tax Evasion in Transition Economies*

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Abstract

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Frequent government changes, often bringing reversals in ideological orientations, forced agents in economies in transition to make economic decisions without knowing whether their next government would be more or less benevolent, democratic, corrupt, or able and willing to pursue economic growth. We present a model of agents facing the uncertainty of two future forms of government, who are able to insure against this uncertainty by opting out of the legal part of the economy. They opt out through a criminal act, specifically, hiding funds from taxation. In order to choose whether or not to steal, agents need to know what each government would do should it come to power. But each government, before it could make its decision, would need to know the choices of the agents who would, for example, produce tax revenues. This informational tension is resolved endogenously. We derive the resulting crime level in society and the optimal choices made by the potential governments. We examine how changes in governmental structure would affect the crime level, and how that, in turn, would affect capital flight.

JEL Classifications: P37, P26, P27, K42

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1. Introduction

Between 1990 and fall 2010, thirty-nine incumbents were replaced in a total of fifty-one elections in the eight Central Eastern European countries that joined the European Union in 2004.¹ These frequent electoral changes, often bringing reversals in ideological orientations, created a climate of political instability as they often resulted in governments pursuing different social and economic policies than their predecessors.² Evidence that economic policy changes have an impact on business decision makers can be found in the BEEPS II data base. Turning to the broader group of twenty-six economies in transition covered in this study, hundreds of respondents from each of these countries were asked many questions, including the following: How great an obstacle to the operation and growth of your business is economic policy uncertainty? In twenty-two of those countries, more than fifty per cent of the respondents stated that economic policy uncertainty was either a moderate or a major obstacle to the operation and growth of their business.³

All the economies in transition suffered immediate drops in output, with real GDP falling for all of them until 1994. Furthermore, only three countries (Poland, Slovenia and Slovakia) had equal or higher real GDP in 1999 than they did in 1989.⁴ The recognition that the economies in transition had outdated capital stocks and pro-

¹See Kornai (2006, Table 4) for the list of the thirty governmental turnovers in these countries between 1990 and 2004. These eight economies in transition were the Czech Republic, Estonia, Poland, Latvia, Lithuania, Hungary, Slovakia and Slovenia. Using the same methodology and countries, and extending the time period to fall 2010, we find thirty-nine instances in which incumbents were replaced.

²We offer another comment on political instability, this time relating to Ukraine, a post-Soviet economy in transition. In Ukraine, ahead of the presidential election in January 2010, policy differences among the top contenders included whether or not to change the constitution to return to presidential rule, whether or not to pursue NATO membership, and whether or not to attempt to renegotiate gas prices with Russia.

³See BEEPS II Interactive Dataset, EBRD–World Bank, 2002. The question can be found under the heading Governance and Anti-Corruption. We excluded Turkey from the panel of countries, leaving the twenty-six economies in transition.

⁴See EBRD *Transition Reports*, various years, and see Campos and Coricelli (2002).

duction methods, and needed thorough redesign in every area, e.g., economic, legal, political, suggests the scope of the problem that any government in that group of countries had to confront. With no recent tradition of democratic government, and in some cases no tradition of democratic government at all, and with the opportunism that the turmoil and early privatization efforts created, it is not surprising that some of the new governments were more benevolent and focused on improving their countries and others were not. It is in this context that the role of uncertainty becomes especially important to agents in the economies in transition. The uncertainty concerning the various possible future policy choices of the government not only affected the economic decisions of the agents, but also created political pressures in support of different governments. Also during this time, and as a consequence of agents' economic decisions, the economies in transition exhibited generally heightened, albeit varying, levels of crime as well as capital flight.⁵ Because of the policy uncertainty during this period, agents were forced to make decisions in the absence of knowing whether the next government would be more or less benevolent, more or less democratic, more or less corrupt, or more or less able and willing to pursue economic growth and infrastructure development.⁶

How would economic agents in an economy in transition have dealt with the significant economic policy uncertainty that they faced? Would this policy uncertainty

⁵See, for example, Lotspeich (1995) for a discussion of empirical evidence relating to the increase in crime rates across transition economies and an analysis of various explanations for the phenomenon. With respect to capital flight, see, for example, Loungani and Mauro (2000), which studies Russian capital flight and compares it with capital flight in the Baltics and Central Europe. They find that Russian capital flight was persistently high, running about \$15billion to \$20billion a year, depending on the definition. The Central Eastern European countries, as well as the Baltics, experienced capital flight early in the transition process, but as economic conditions improved, inflows of capital became the norm until the financial/economic crisis beginning in 2008.

⁶Of course, at any election point, there is uncertainty about the policies of the government that will emerge as the victor. In the postcommunist period, however, both political instability and divergent ideologies were hallmarks of the economies in transition. For this reason, we set our problem in the context of the economies in transition, although the implications of our analysis may also be pertinent more widely.

have induced acts by these agents that would have undermined or impeded the development of stable market-oriented democracies? In this paper, we attempt to answer these questions by investigating the degree to which uncertainty concerning future governmental policy induces crime on the part of agents and how this, in turn, has an impact on economic development.

In our model we consider agents in a country in an early stage of transition from a planned to a market economy and suppose the transfer of property rights, once held by the state, has already occurred. However, the transition is still in progress, and the nature of the government's future policies is unknown to the agents. In particular, we assume that the agents believe that, due to a variety of reasons, the present government may evolve into either a benevolent democratic government or a corrupt government. Each agent is forced to make economic decisions relating to his firm prior to the knowledge of which government will come into existence. The agent must choose whether or not to shelter some of the firm's funds out of the reach of the tax authorities to compensate for the uncertainty he faces. We refer to this illegal act (crime) of diversion of funds by the agent as stealing. In choosing whether or not to steal, and how much to steal, the agent needs certain information. We assume that the agent needs to know, among other things, the probability that each government would come into existence and what each of the governments would do if it did come into existence. Knowing these things, each agent makes his economic choice, and collectively these choices yield both the tax revenue that would go to the ensuing government, and the level of crime, denoted by the proportion of agents who avoid taxes. On the other hand, agents believe that each government, should it come into existence, will optimize its own objectives. These objectives may depend on the crime level and will be limited by the tax revenues provided by the agents. However, the crime level itself will be affected by the decisions of the ensuing government. Thus, the agents need the governments' decisions to solve their problems and the

governments need the agents decisions to solve their problems. The tension between the agents and governments is resolved by endogenizing the probabilities that each government will come into existence, thus bringing these two sets of decisions into accordance. The result of the equilibrium is to produce the crime level, and should the democratic government come into existence, the optimal level of investment in infrastructure this government would choose.

To investigate some policy implications of our model, we next explore the impact of changes in the model's parameters on the crime level and the democratic government's investment in infrastructure. We then define capital flight within the context of tax evasion and show how it would be affected by changes in the model's parameters.

In the context of the literature on the rule of law in transition economies, most models investigating the decisions of agents in transition economies to steal start with a benchmark case in which the agents face a known type of government. The agent optimizes given the existing government, and then the problem is re-solved under the assumption of a different form of government. The agents' decisions in the two situations are then compared. Although agents make decisions in two different contexts, there is no self-awareness on the part of the agent that the government might be of different types. Examples of such studies include Polishchuk and Savvateev (2004), Roland and Verdier (2003), Sonin (2003), and Katz and Owen (2009). A particular type of government, known to the agents, is also assumed in Grossman (1995) and Alexeev, Janeba and Osborne (2004), which focus on "mafias" competing with the state for entrepreneurial rents. Dixit (2004), which suggests a principal-agent model to capture the intent of a government to induce efficiency in society, also assumes a given governmental form, known to the agents. Hoff and Stiglitz (2004) take a different tack by assuming agents face uncertainty regarding the form of government that will arise. They endogenize the probability of occurrence of these governments using a consistency requirement among the agents, and find that the

uncertainty of governmental form leads to multiple solutions for the crime level. In their model the agents do not consider an active government in making their choices.

We contribute to the literature on the rule of law in transition by considering the impact of political uncertainty on crime in a broader context than the literature mentioned above. The considerations that the agents face in our model include not only the uncertainty of the future form of government, but also the awareness that their collective decisions have an impact on which government will come into existence, and also on what each government would do if it did come into existence. Taking these awarenesses into account, we derive the level of crime resulting from them. We further examine how changes in this level of crime would be affected by changes in the parameters describing these governments. This leads us to offer certain policy suggestions. We are also able to investigate how changes in capital flight would relate to changes in the parameters.

We also contribute to the literature on the role of institutions in transition (for example, Djankov and Murrell (2002), McMillan (2002) and Bevan and Estrin (2004), and to that stressing the importance of institutional arrangements (for example, Shleifer and Vishny (1998), and Acemoglu, Johnson and Robinson (2001, 2002, 2003)). We add to this literature by showing that different economic outcomes are to be expected when we allow agents to make choices in the face of the uncertainty as to which institutional arrangements will prevail.

We present our model in Section 2. In Section 3 we discuss our results and offer our conclusions.

2. Model

2.1. The Agent's Problem

We begin by assuming that all agents believe that the present government is in flux and will evolve by the end of the period into one of two possible forms that are known to the agents. We designate the two forms as G1 and G2. G1 is a benevolent, democratic government that is concerned with determining its growth rate r , $r \in \mathbb{R}$, so that it maximizes its objective function. That objective function depends on growth and the crime level, albeit constrained by its tax revenue and the costs associated with generating growth. G2 is a corrupt government that is interested in maximizing the difference between its tax revenue and its costs of maintaining the status quo for its own purposes. G2 chooses the severity by which it punishes crime in order to maximize its objective function. Thus, at the outset, agents must make decisions in the face of the uncertainty of governmental form, and also with the awareness that their choices will alter the tax revenues and the crime level, and hence the decisions made by the particular government that does come into being. In fact, the ultimate choice of governmental form may itself depend on the collective decisions of the agents.

There is a continuum of expected value maximizing agents a , $a \in [0, 1]$, each of whom owns one firm, the value of which is normalized to 1. Operating a firm honestly might turn out to be unrewarding if G1 were to come into existence and, due to shortfalls in tax revenue, could only offer a negative growth rate. In this case, it could be beneficial for the agent to steal some of the firm's funds to insure against this potential loss. On the other hand, should the agent choose to insure against this loss by stealing, and G2 were to come into existence and the agent were caught stealing, the result could be severe. This motivates us to begin our model by assuming that the agent must decide whether or not to steal assets from the firm, and if he chooses to steal, the amount to steal. We let $\tau_a, \tau_a \in [0, 1]$ be the proportion agent

a chooses to steal from the firm. We assume that the probability that an agent who steals τ_a will be caught is given by a . This probability of being caught is invariant to the subsequent form of government.

We first consider the outcomes for the agent should G1 come into existence. If agent a chooses to steal $\tau_a > 0$ proportion of the firm and is not caught, he keeps the stolen funds τ_a , and the remainder of the firm, which we assume is honestly run, at the end of the period is worth $(1 - t)(1 - \tau_a)(1 + r)$, where $t, t \in [0, 1]$, is the tax rate and $r, r \in \mathbb{R}$, represents the impact of the economic growth generated by G1. If agent a is caught, then the agent must return the stolen funds to the government, plus pay a penalty i.e., he must pay back to the government $\tau_a(1 + \delta)$, $\delta > t$. The part of the firm not stolen, which we assume to have been run honestly, will be taxed at the rate t , and, at the end of the period, will be worth $(1 - t)(1 - \tau_a)(1 + r)$. Thus, agent a retains $(1 - t)(1 - \tau_a)(1 + r) - \delta\tau_a$ of the firm at the end of the period. If agent a chooses not to steal ($\tau_a = 0$), then the firm will be worth $(1 - t)(1 + r)$ at the end of the period. Under G1, the expected value to agent a of stealing $\tau_a > 0$ can be written as $E_1(\tau_a) = (1 - t)(1 + r) - \tau_a[a(1 + \delta) + (1 - t)(1 + r) - 1]$. Under G1, the expected value to agent a of stealing $\tau_a = 0$ is $E_1(0) = (1 - t)(1 + r)$.

We now consider the outcomes for the agent should G2 come into existence. If agent a chooses to steal $\tau_a > 0$ and is not caught, he pockets τ_a and the remainder of the firm is honestly run and worth $(1 - t)(1 - \tau_a)$ at the end of the period, where t is the same tax rate as in G1. Since G2 does not create a climate conducive to economic growth, the value of the firm remains constant. If agent a is caught stealing, then he is punished by having to pay a penalty f , $f \in [t, f_0]$, where $f_0 \geq 1 + \delta$, on the entire firm to the government. If agent a chooses not to steal, then the firm is worth $(1 - t)$. Under G2, the expected value to agent a of stealing $\tau_a > 0$ can be written as $E_2(\tau_a) = (1 - a)(1 - t) + a(1 - f) + \tau_a(1 - a)t$. Under G2, the expected value to agent a of stealing $\tau_a = 0$ is $E_2(0) = (1 - t)$.

To complete the calculation of the expected value for agent a , agent a must ascribe a probability to the coming into existence of G1 or G2. We let π , $\pi \in [0, 1]$, represent the probability of G1 coming into existence, and $(1 - \pi)$ the probability of G2 coming into existence. Given π , the expected value to agent a of stealing $\tau_a > 0$, $E(\tau_a) = \pi E_1(\tau_a) + (1 - \pi)E_2(\tau_a)$, can be written as

$$E(\tau_a) = \pi(1 - t)(1 + r) + (1 - \pi)[a(1 - f) + (1 - a)(1 - t)] + \tau_a\{(1 - a)t - \pi[a(1 - t + \delta) + r(1 - t)]\}. \quad (2.1)$$

Given π , the expected value to agent a of stealing $\tau_a = 0$ is $E(0) = \pi E_1(0) + (1 - \pi)E_2(0)$, which can be written as

$$E(0) = \pi(1 - t)(1 + r) + (1 - \pi)(1 - t). \quad (2.2)$$

In these expressions, t and δ are taken to be parameters, but r is to be determined by G1 should it come into existence, and f is to be determined by G2 should it come into existence. Conditional on π , r , and f , the optimum value of τ_a , denoted by τ_a^* , is summarized in the following proposition. The proof of this proposition and all subsequent propositions can be found in the Appendix.

Proposition 1. Given π , r , and f , $\tau_a^* = \begin{cases} 1 & \text{if } a < b(\pi, r, f) \\ 0 & \text{if } a \geq b(\pi, r, f) \end{cases}$
where $b(\pi, r, f) = \frac{t - \pi(1 - t)r}{f + \pi(1 + \delta - f)}$.

Although agents believe that r and f are to be chosen optimally by G1 and G2, respectively, the value of π should reflect the agents' common view of the probability that G1 will come into existence. The way the agents determine π depends on the process that will lead to the selection of G1 or G2, as well as the decisions that these

governments would make should they come into existence. In the next section, we address the way in which π is endogenized and reevaluate τ_a^* using this derived form of π . (The notation τ_a^* will remain when we subsequently insert the optimum values of π , r , and f .)

2.2. The Conditional Crime Level and Endogenization of π

We begin by evaluating the conditional crime level. By indexing agent a on the probability that the agent will be caught, we are allowing that some agents are better thieves than others. How they are distributed in society is assumed to be given by the distribution function $H(a)$, $a \in \mathbb{R}$, where $H(a) = 0$ for $a \leq 0$, $H(a) = 1$ for $a \geq 1$, and $H(a)$ is continuous. The crime level conditional on π , r , and f , denoted by $K(\pi, r, f)$, is given by the proportion of agents that steal given π , r , and f . It follows from P1 that $K(\pi, r, f) = \int_0^{b(\pi, r, f)} dH(a)$ and $0 \leq K(\pi, r, f) \leq 1$. (*Cet. par.*, $K(\pi, r, f)$ is decreasing in the growth rate r .) We now address π .

The value of π must be determined before agents can decide what proportion, if any, of the firm to divert to themselves, i.e., to shelter from the tax authorities. At the outset, agents have no information about the crime level, tax revenues, or government policies, but can decide how they would determine π when such information becomes available. Also at the outset, before deciding whether or not to steal, we assume all agents prefer higher growth rates and lower crime levels. Since G1's objective is to produce higher growth rates and lower crime levels, we assume that agents would be more supportive of G1 the more they perceive G1 to be successful in achieving its objectives. That is, we assume that agents perceive π to be a function of the growth rate and the crime level, increasing in the first and decreasing in the second. The proportion of honest agents, $1 - K(\pi, r, f)$, is decreasing in the crime level and, from the preceding paragraph, it follows that it is increasing in the growth rate. Thus, this function can serve as a basis for determining π . We proceed to endogenize π by

assuming that agents will agree on the value of π that satisfies $\pi = 1 - K(\pi, r, f)$.

We next establish the solution to the equation $\pi = 1 - K(\pi, r, f)$. To emphasize the conditionality of this solution, we denote it by $\pi(r, f)$ and the resulting conditional crime level as $K(r, f)$.

For the remainder of the model, we set $H(a) = a$ for $a \in (0, 1)$. When $H(a)$ is uniform, $K(\pi, r, f) = b(\pi, r, f)$ for $b(\pi, r, f) \in (0, 1)$, $K(\pi, r, f) = 0$ for $b(\pi, r, f) \leq 0$ and $K(\pi, r, f) = 1$ for $b(\pi, r, f) \geq 1$. Several results hold for other distribution functions as we note in our concluding section.

Proposition 2. *Given r and f*

(a) *If $r \geq t/(1 - t)$, then $\pi(r, f) = 1$.*

(b) *If $r < t/(1 - t)$, then $\pi(r, f)$ is the unique root in $[0, 1)$ satisfying $(f - 1 - \delta)\pi^2 - [f - (1 + \delta - f) - (1 - t)r]\pi + f - t = 0$.*

Having established the unique root $\pi(r, f)$, we now return to P1 and evaluate τ_a^* using this value. We present the results in the next proposition.

Proposition 3. *Given r and f*

(a) *If $r \geq t/(1 - t)$, then $\tau_a^* = 0$ for all a .*

(b) *If $r < t/(1 - t)$, then $\tau_a^* = 1$ if $a < 1 - \pi(r, f)$ and $\tau_a^* = 0$ if $a \geq 1 - \pi(r, f)$.*

Having shown the way in which $\pi(r, f)$ and τ_a^* depend on r and f , agents must now consider the way in which r and f would be chosen by G1 and G2, respectively.

2.3. Determining Optimum Choices for G1 and G2

Agents believe G1 and G2 would determine the optimum values of r and f , respectively, if they were to come into being. The agents derive these values by assuming, in turn, that each government would optimize its objective function if it were to come into existence. We begin with G1.

If G1 were to come into existence, the agents clearly would know this. Thus, the only uncertainty the agents would face when considering how much to steal would be whether or not they would be caught. Using the expected values for agent a given in subsection 2.1 above under the condition of G1's existence, agent a would have to evaluate the conditions under which he would steal or not steal. These evaluations would lead to the results of the previous subsections when π is set equal to 1. That is, under G1, $\tau_a^* = 1$ if $a \leq [t - (1 - t)r]/(1 + \delta)$ and 0 otherwise. Under these circumstances, $b(\pi, r, f)$ becomes $\frac{t-(1-t)r}{1+\delta}$ which we denote by $b_1(r)$. The corresponding conditional crime level is denoted by $K_1(r)$. It follows that $K_1(r) = b_1(r)$ for $[t - (1 + \delta)]/(1 - t) < r < t/(1 - t)$, $K_1(r) = 1$ for $r \leq [t - (1 + \delta)]/(1 - t)$ and $K_1(r) = 0$ for $r \geq t/(1 - t)$. Thus, the conditional crime level $K_1(r)$ is non-increasing in r , and therefore the proportion of honest agents is a non-decreasing function of r . Since G1's objective function is assumed by the agents to be the weighted sum of the growth rate r and the proportion of honest agents, this objective function is an increasing function of the growth rate r . Consequently G1 will choose r as large as possible subject to its fiscal constraint. This constraint is determined by G1's tax revenue $T_1(r)$, minus the cost, $C(r)$, associated with producing the growth rate r . The tax revenue $T_1(r)$ is composed of revenue from the honestly run firms as well as from the penalties levied when the thieves are caught. Thus, $T_1(r) = \int_0^1 [a\tau_a^*(1 + \delta) + t(1 - \tau_a^*)(1 + r)]dH$. We next present the explicit form of $T_1(r)$.

Proposition 4. $T_1(r) = \begin{cases} t(1 + r) & \text{if } r \geq t/(1 - t) \\ (1 + \delta)/2 & \text{if } r \leq [t - (1 + \delta)]/(1 - t) \\ \frac{1+\delta}{2}b_1^2(r) + t(1 + r)[1 - b_1(r)] & \text{if } \frac{t-(1+\delta)}{1-t} < r < t/(1 - t) \end{cases}$

where $b_1(r) = \frac{t-(1-t)r}{1+\delta}$.

Because the objection function is increasing in r , G1 will choose r as the largest r such that $T_1(r) \geq C(r)$.

If we assume that $C(r)$ is a convex increasing function of r with derivatives $C_r(-\infty) = 0$ and $C_r(\infty) = \infty$, then G1 will choose r as the largest r such that $T_1(r) = C(r)$. We let r^* be the solution.

P4 demonstrates that the tax revenue function is constant up to the value $r = \frac{t-(1+\delta)}{1-t}$ and then becomes a convex parabola, initially decreasing, reaching a minimum and then increasing to the value $r = t/(1-t)$, beyond which it becomes a linear increasing function of r . To better understand the shape of $T_1(r)$, we stress that this shape is the input to G1's considerations in choosing the optimum value of r . From this perspective, every agent would be a thief if $b_1(r) = 1$, i.e., if $r \leq \frac{t-(1+\delta)}{1-t}$. As soon as r exceeds this value, some agents become honest. For each agent who becomes honest, the change in tax revenue that G1 anticipates is made up of the difference between the new tax paid by the now-honest agent and the loss of penalty payment that that agent, as a former thief, would have paid if he had been caught. Since the value of r that immediately precedes $\frac{t-(1+\delta)}{1-t}$ is negative, the tax revenue would be based on a reduced value of the firm, which is less than the amount G1 would anticipate if the agent had been dishonest and had been caught. Thus, there would be an anticipated loss of revenues. As r increases and additional agents become honest, this difference remains negative until r is sufficiently large so that the additional tax revenue exceeds the loss of the penalty payments.

The expression for $T_1(r)$ explicitly ties the tax revenue to the crime level $K_1(r) = b_1(r)$. However, this crime level, as argued above, is only the crime level under the assumption that governmental uncertainty has been removed. This crime level is, of course, not the same as the crime level that would result from the behavior of agents facing the uncertainty over governmental form. We now turn to G2.

Agents believe G2's objective is to choose $f \in [t, f_0]$ to maximize its tax revenue minus the fixed cost of maintaining the status quo. If G2 were to come into existence, the agents would clearly know this and agent a would again have to evaluate the

conditions under which he would steal or not steal. These evaluations would lead to the results of subsection 2.1 above when π is set equal to 0. That is, under G2, $\tau_a^* = 1$ if $a \leq \frac{t}{f}$ and 0 otherwise. Let $b_2(f) = \frac{t}{f}$. G2's tax revenue is also composed of revenue from honestly run firms as well as from penalties levied when thieves are caught. Thus its tax revenue $T_2(f) = \int_0^1 [fa\tau_a^* + t(1 - \tau_a^*)]dH$. Evaluating the revenue and subtracting the fixed cost of the status quo, $C(0)$, we have that G2's objective function is $t - \frac{1}{2}\frac{t^2}{f} - C(0)$. Since this expression is increasing in f , G2 maximizes its objective function by choosing $f^* = f_0$.

Having determined r^* and f^* , the agents now evaluate $\pi^* = \pi(r^*, f^*)$. Then, using this value, the agents can calculate $b^* = b(\pi^*, r^*, f^*)$ and subsequently τ_a^* . Collectively, the choices of the agents yield the crime level $K^* = K(\pi^*, r^*, f^*) = b^*$.

2.4. Example

To illustrate the results derived above, we now present a special case of the model that brings the two governments under consideration into clearer focus. In this special case, we assume that the penalty chosen by G2 is the same as that adopted by G1, i.e., that $f^* = f_0 = 1 + \delta$. With this simplifying assumption, each agent is reduced to comparing a growth rate optimally chosen by G1 with the status quo maintained by G2.

Since the cost function $C(r)$ is independent of the tax revenue $T_1(r)$, then any r^* can be chosen in this example by judiciously selecting the cost function. The most interesting results derived in the propositions above occur when $r < t/(1 - t)$. Thus, in this example, we set $r^* = \alpha^* \frac{t}{1-t}$ where $\alpha^* < 1$.

To further simplify the notation of this example, we write $1 + \delta$ in units of the tax rate, i.e., we set $f^* = f_0 = 1 + \delta = nt$ with $n > 1$. With this assumption and change of notation, the equation of π^* in P2 part (b) becomes linear and yields $\pi^*(r^*, f^*) = \frac{n-1}{n-\alpha^*}$. Using the definition of $b(\pi, r, f)$ given in P1 and the fact that

$K(\pi, r, f) = b(\pi, r, f)$ in our model, it follows for this example that $K^*(\pi^*, r^*, f^*) = b^*(\pi^*, r^*, f^*) = \frac{1-\alpha^*}{n-\alpha^*}$. Finally, from P1, $\tau_a^* = 1$ if $a < \frac{1-\alpha^*}{n-\alpha^*}$ and $\tau_a^* = 0$, otherwise.

For this example, no matter which r^* is chosen by G1, neither government will ever be the unambiguous choice of the agents, i.e., $0 < \pi^*(r^*, f^*) < 1$, for $r^* > -\infty$. Reflecting this observation is the fact that there will always be some level of crime, i.e., $K^*(\pi^*, r^*, f^*) > 0$, no matter the value of r^* . This is also shown in the value of τ_a^* where there are always agents for whom $\tau_a^* > 1$.

Now consider an increasing sequence of n values and, correspondingly, a sequence of cost functions that, for each of these n values, yields $r^* = 0$, i.e., $\alpha^* = 0$. This produces a sequence of π^* and K^* values. The sequence of π^* values is strictly increasing in n and the sequence of K^* values is strictly decreasing in n . When $r^* = 0$, the growth rate is the same for G1 and G2, yet $\pi^* = 1/2$ only if $n = 2$. The reason for this is that $K^* = 1/2$ only for $n = 2$. The value of π^* will increase or decrease from $1/2$ as K^* decreases or increases from $1/2$. This is consistent with our assumption that agents, before having made their choices, consider both growth and crime in their determination of π . These properties of the example can be shown to hold in the general case.

The conclusions of the last paragraph do not hold if we keep the cost function fixed and increase the value of n , since in this case, $T_1(r)$ will change and, as a consequence, $r^* \neq 0$. Thus, we need a different approach to explore the consequences of changing parameter values in our model. We address this in the next section.

2.5. Comparative Statics: r^*

In order to investigate how changes in the fundamental parameters δ , t , and f_0 would affect the level of crime or the support the agents might provide for a particular government, we must first analyze how the government's choices of r^* and f^* , respectively, change with these parameters. In what follows, the subscript θ under a

function denotes partial differentiation with respect to the subscripted variable.

Proposition 5. For $\theta = \delta, t,$ or f_0 , $sign \frac{dr^*}{d\theta} = sign T_{1\theta}(r^*)$.

Using P4, we differentiate $T_1(r)$ and, depending in which region r^* is found, we can determine the sign of $\frac{dr^*}{d\theta}$ as required by P5. We focus on the sign since, as can be seen in the proof of P5, the magnitude of $\frac{dr^*}{d\theta}$ depends on the reciprocal of $T_{1\theta^*} - C_{r^*}$ and therefore can have any value depending on the specific specifications of the model. This leads to the next proposition.

Proposition 6. (a) $\frac{dr^*}{d\delta} \geq 0$ for all r^* except for $r^* \in \{[t - (1 + \delta)]/(1 - t), -t/(1 + t)\}$ where $\frac{dr^*}{d\delta} < 0$.

(b) $\frac{dr^*}{dt} \geq 0$ for all r^* except for $r^* \in \{[t - (1 + \delta)]/(1 - t), -1\}$ and for $r^* \in \{\min[(1 + \delta - t)/t, t/(1 - t)], t/(1 - t)\}$ where $\frac{dr^*}{dt} < 0$.

(c) $\frac{dr^*}{df_0} = 0$ for all r^* .

(d) $\frac{df^*}{dt} = 0, \frac{df^*}{d\delta} = 0$ for all f_0 except when $f_0 = 1 + \delta$ where $\frac{df^*}{d\delta} > 0$.

(e) $\frac{df^*}{df_0} > 0$.

In parts (a)-(c) of P6, we consider changes in r^* with respect to changes in the parameters. As such, we are considering the agents' problem from the view point of G1 having come into existence. In part (a) we show that generally an increase in the penalty for crime allows G1 to increase r^* . There is, however, an exception to this, that occurs when the r^* that G1 can afford falls into the negative range given in part (a). The attempt to increase the penalty in this range reduces r^* since raising the penalty has two impacts. One is to increase revenue and the other is to decrease the crime level. In this range, an agent who was a thief and was caught and who would have paid G1 the additional amount $d\delta$ is now honest, and pays the tax of $t(1 + r^*)$. Since r^* here is negative, part (a) establishes that the net effect to G1 is negative.

In part (b) of P6, we find that an increase in the tax rate generally allows G1 to choose a large r^* . This is not true when $r^* \in \{[t - (1 + \delta)]/(1 - t), -1\}$, where for similar reasons as discussed in the paragraph above, $\frac{dr^*}{d\delta} < 0$. However, in part (b), there is a second possible interval, $r^* \in \{\min[1 + \delta - t]/t, t/(1 - t)\}$ where $\frac{dr^*}{dt} < 0$. This interval vanishes unless $[(1 + \delta - t)/t] < [t/(1 - t)]$ or when $t > [(1 + \delta)/(2 + \delta)]$. For $r^* > 0$, increasing t has two effects, increasing revenue and increasing the crime level. Thus, an agent who was honest and would have paid the additional amount of taxes $dt(1 + r^*)$ would now become a thief and, if caught, pay $1 + \delta$. Depending on the size of r^* , the net effect of this change could be either positive or negative, but part (b) establishes the relationship between t and δ that causes the net effect on G1 to be negative. In sum, parts (a) and (b) imply that the normal intuition that raising taxes, whether on crime (δ) or on honest agents (t), will increase revenues and therefore the options of G1, is correct. However, parts (a) and (b) also imply that this intuition is incorrect in extreme cases as specified in the proposition. In these extreme cases, the raising of taxes could worsen the situation. Since r^* does not depend on f_0 , part (c) follows.

In parts (d) and (e) agents are considering the problem from the viewpoint of G2 having come into existence. Since $f^* = f_0$, parts (d) and (e) follow.

Having established how r^* changes with changes in the parameters of the model, we next examine how the crime level would correspondingly change. Then we introduce the concept of capital flight into our model and investigate how it would change with parametric changes.

2.6. Comparative Statics: Crime and Capital Flight

Because agents are uncertain as to the future form of government and its policies, stealing may occur and, as we showed above, this leads to a level of crime K^* . Of the funds stolen, some were not recaptured by the government and remained undetected.

We assume below that these undetected stolen funds form the basis of capital flight. In this section we are concerned with how the crime level changes with changes in our parameters δ , t and f_0 , and, subsequently, with the impact of changes in the crime level on capital flight. We begin by studying the crime level.

Proposition 7. *Under P6,*

(a) $\frac{dK^*}{d\delta} < 0$ if $r^* \notin \{[t - (1 + \delta)]/(1 - t), -t/(1 + t)\}$.

(b) *There exists a constant r_0 with $r_0 < -1$ such that $\frac{dK^*}{dt} > 0$ if r^* is either $\{\max[r_0, (t - (1 + \delta))/(1 - t)], -1\}$ or $\{\min[(1 + \delta - t)/t], t/(1 - t)\}$. When r^* is in neither interval, $\text{sign} \frac{dK^*}{dt}$ can be positive or negative depending on parameter values.*

(c) $\frac{dK^*}{df_0} < 0$.

The function $K^* = b^*$ depends on δ in possibly four ways: through π^* , through r^* , through f^* , and directly through δ . Thus, the sign of $\frac{dK^*}{d\delta}$ must reconcile the contributions of each of these four ingredients. We interpret part (a) first. Although some of these ingredients are of opposite signs, when $r^* \notin \{[t - (1 + \delta)]/(1 - t), -t/(1 + t)\}$ their sum is always negative. Marginally, increasing δ causes a decrease in the crime level. An agent who had been a thief and would have provided a penalty to G1 if caught, would now be honest and would pay taxes. The difference of these two payments to G1 is what G1 gains as δ is increased. Usually, the tax contribution is larger than the penalty contribution from the caught thief, yielding an increase in revenue. Thus, both an increase in δ and an increase in revenue produce a decline in the crime level. However, when r^* is in the interval $\{[t - (1 + \delta)]/(1 - t), -t/(1 + t)\}$, the net effect of these two payments is negative, causing r^* to decline. The effect of this is marginally to increase the crime level. Thus, there are two opposing forces, one to increase and one to decrease the crime level. The reconciliation of these two forces here depends on the parameter values. Thus, if one were considering reducing crime

by increasing the penalty for stealing, it would be important to take into consideration the state of economic development to avoid worsening the situation. In particular, in those economies in transition with very negative growth rates, controlling crime by increasing penalties might be counter-productive.

We now turn to part (b). Let r^* in part (b) be in the interval $\{\max[r_0, (t - (1 + \delta))/(1 - t)], -1\}$. Examining the form of $K^* = b^*$, a marginal increase in t causes b^* to increase. Also, from P6, we showed that an increase in t causes r^* to fall, marginally causing b^* to rise. Thus, unambiguously, the crime level rises. In the positive interval, if it exists, again the marginal effect of t is to increase the crime level. From P7, since r^* declines with t , this latter effect also causes b^* to increase and thus unambiguously the crime level increases with t . Outside these two intervals, the marginal effect on t and its consequences on r^* yield opposite effects on the total crime level that can only be resolved with knowledge of the particular parametric values. The difficulty of assigning a sign to $\frac{dK^*}{dt}$ for most values of r^* stems from the assumption of convenience that we made at the outset that t is the common tax rate for both G1 and G2. Since f_0 enters b^* only through f^* and since b^* declines with f^* , part (c) follows.

In the discussion following P7, the contribution of π^* to the change in K^* was not mentioned. Since at optimality, $\pi^* = 1 - K^*$, π^* was absorbed into K^* in this discussion.

We next assume that a portion of the undetected stolen funds leave the country as capital flight. For ease of presentation, we assume that capital flight, denoted by F , is equal to the total undetected stolen funds.

From earlier discussions, $F = \int_0^1 (1 - a)\tau_a^* dH = \int_0^{b^*} (1 - a)dH = b^* - \frac{b^{*2}}{2} = \frac{1 - [1 - K^*]^2}{2}$ if $0 < b^* \leq 1$ and $F = 0$ otherwise. This enables us to describe changes in F in terms of changes in the crime level which we do next.

Proposition 8. For $\theta = \delta, t,$ or $f_0,$

$$\frac{dF}{d\theta} = \begin{cases} 0 & \text{if } r^* \geq t/(1-t) \\ (1 - K^*) \frac{dK^*}{d\theta} & \text{if } r^* < t/(1-t) \end{cases}.$$

P8 establishes the direct connection between capital flight and the crime level and, in particular, how changes in the one induce changes in the other. When $r^* > t/(1-t)$, all agents are honest, the crime level is zero, and small changes in δ , t , and f_0 , cause no change in capital flight. When $r^* \leq t/(1-t)$, changes in capital flight will occur and depend on the crime level and its derivative. We next ascertain the direction of this change.

Proposition 9. *Let $r^* < t/(1-t)$, then*

(a) $\frac{dF}{d\delta} < 0$ if $r^* \notin \{[t - (1 + \delta)]/(1 - t), -t/(1 + t)\}$.

(b) $\frac{dF}{dt} > 0$ if r^* is in either $\{\max[r_0, [t - (1 + \delta)]/(1 - t)], -1\}$ or $\{\min[(1 + \delta - t)/t, t/(1 - t)], t/(1 - t)\}$ where r_0 is given in P7. When r^* is in neither interval, the sign of $\frac{dF}{dt}$ can be positive or negative, depending on the parameters.

(c) $\frac{dF}{df_0} < 0$.

Since $\text{sign} \frac{dF}{d\theta} = \text{sign} \frac{dK^*}{d\theta}$, the discussion following P7 is pertinent to all of the results of P9. It is worth noting again that an attempt to control capital flight by raising the penalty on thieves might fail if the attempt is made in an economy with a sufficiently negative growth rate. Similarly, a rise in the tax rate can also have undesired consequences on capital flight depending on the state of the economy.

3. Discussion and Conclusions

We presented a model of agents facing political uncertainty who were able to insure against this uncertainty by opting out of the legal part of the economy through hiding funds from taxation. By allowing agents this choice, the crime level in society emerged and dominated the discussions of all of the features of the model. Not only did the

crime level have the usual interpretation, but it also was a major factor in determining tax revenues the potential governments could expect. As a consequence, the crime level also became an important factor in the optimum choices of the governments. Our model suggests that in a world in which such illegal options exist, ignoring them may bias conclusions and policy implications.

A feature of our model worth noting is that of asymmetric information. When agents confront the decision to illegally divert funds, they face two sources of uncertainty: Not knowing which government will come into being and not knowing if they would be caught if they stole funds. Based on these two sources of uncertainty, the model determined the crime level that would ensue. But there were two other crime levels that were also involved in the model. When the agents assumed that G1, having come into being, optimized its objective function subject to its fiscal constraint, G1 needed to anticipate the crime level since the crime level was part of its objection function, as well as a contributor to its tax revenue. But agents facing G1, assuming it had come into existence, have only one source of uncertainty to contend with, namely, the uncertainty of being caught when stealing. Therefore, the crime level as perceived by G1 in this circumstance is different from that as perceived by the agents before imagining G1 had come into existence. Similarly, a third crime level was determined when agents imagined G2 had come into existence. Since the agents need to know the optimum choices of the governments before they can make their own choices, it follows that the actual tax revenue produced by the agents would not be the tax revenue used by the governments to optimize their choices, and that the crime level produced by the agents would not be the ones used by the governments to optimize their choices. While, for example, it is always true that the crime level produced by the agents under full uncertainty is between those conceived of by G1 and G2, the relative sizes of these latter two crime levels depend on information that is not available to either government. The implications of these discrepancies remain

to be analyzed.

In the model, two assumptions were made concerning the ways the set of agents select the subjective probability, π , that G1 will come into existence. First, we assumed that the more agents believed that G1 could obtain its objectives, the higher π would be, and conversely. The second assumption was to set π equal to a particular function that was shown to move in accordance with G1's objectives. These two assumptions permitted us to endogenize the value of π and to proceed to analyze the full model. Obviously, the particular function we chose might have been different, but if it still satisfied our first assumption, then we believe that the results would not have substantially changed.

The importance of the crime level in our model is underscored by its complexity. We showed that, among other things that it depended upon, the crime level depended on π^* , the agreed upon probability that G1 would come into existence, r^* , the growth rate chosen by G1, and f^* , the penalty rate chosen by G2. All of these optimized values depend on the perceived behavior of groups of agents and the structural values defining each government. Because of the importance of the crime level in policy-making, governments might consider controlling this level by altering the structural values. The result of our study shows that changes in these values do not necessarily yield desirable changes in the crime level. That is, due to the complexity just mentioned, changes in the structural values can lead to unintended changes in the crime level. Since capital flight in our model is directly related to the crime level, it follows that any attempt to control capital flight by altering structural values should be done in light of these possible unintended consequences.

Our model was formulated to explain some of the challenges faced by agents in the economies in transition. To that end, we derive, among other things, the crime level in a particular stylized country. But how can the model speak of different crime levels in different countries? We answer this question by thinking of an economy as

made up of three elements: First, the structural form of possible future governments faced by the agents, second, the distribution of agents' skills $H(a)$, and third, the cost $C(r)$ in the economy of achieving a growth rate r . These elements need to be chosen to match the characteristics of a given country. For example, the two possible governmental outcomes could involve less democratic options and more draconian options. Also, a country might initially be more corrupt than another and thus $H(a)$ might increase faster for the more corrupt country. Finally, one country could initially be poorer than another, or less able to attract or be granted funds, implying that its cost of improving the infrastructure would be larger. Specifying these values for a given country, we would proceed in the development of the corresponding model. However, depending on how far afield these elements are from those assumed in our model, the development itself might become more complex. For example, if $H(a)$ were specified not to be uniform but to be convex, the development would go through essentially unchanged. But, more complicated specifications of these distribution might lead to multiple solutions and the problems associated with those solutions. However, by changing the form of these three elements, singly or in combination, while maintaining the essential argument developed in this paper, we are able to offer a partial explanation for the differences in crime levels, capital flight and growth rates in the the economies in transition.

4. Appendix

Proof of P1. Agent a will choose $\tau_a^* = \arg \max[E(0), \max_{0 < \tau_a \leq 1} E(\tau_a)]$. (A tie in expected values is assumed to lead agent a to be honest.) Since $E(\tau_a)$ is linear in τ_a , agent a will choose $\tau_a = 0$ or $\tau_a = 1$. The intercept of this line is less than $E(0)$. This follows by setting $\tau_a = 0$ in equation 2.1, and comparing that result to $E(0)$, noting that $f \in [t, f_0]$. Thus, a necessary and sufficient condition that $\tau_a^* = 1$ is

$E(\tau_a = 1) - E(0) > 0$. Using equations 2.1 and 2.2,

$$\begin{aligned}
E(\tau_a = 1) - E(0) &= (1 - \pi)[a(1 - f) + (1 - a)(1 - t) - (1 - t)] + t \\
&\quad - \pi(1 - t)r - a[t + (1 + \delta - t)\pi] \\
&= t - \pi(1 - t)r - a[t + (1 + \delta - t)\pi + (1 - t)(1 - \pi)] \\
&= t - \pi(1 - t)r - a[f + (1 + \delta - f)\pi].
\end{aligned}$$

This last expression is positive if and only if $a < \frac{t - \pi(1 - t)r}{f + \pi(1 + \delta - f)}$. Thus, $\tau_a^* = 1$ if the last inequality holds and $\tau_a^* = 0$ otherwise. ■

Proof of P2. Let $r = t/(1 - t)$. Then $b(\pi, r, f) = \frac{t(1 - \pi)}{f + \pi(1 + \delta - f)} \geq 0$. Substituting $b(\pi, r, f)$ for $K(\pi)$ in the equation $\pi = 1 - K(\pi)$ yields the equation $\pi = 1 - \frac{t(1 - \pi)}{f + \pi(1 + \delta - f)}$ which has $\pi = 1$ as its solution. For $r > t/(1 - t)$, $b(\pi, r, f)$ is negative at $\pi = 1$. Thus, $K(\pi) = 0$ at $\pi = 1$ so that $\pi = 1 - K(\pi)$ has the solution $\pi = 1$. This establishes part (a).

To show part (b), we note that for $r < t/(1 - t)$, $b(\pi, r, f) > 0$. Substituting $b(\pi, r, f) = \frac{t - \pi(1 - t)r}{f + \pi(1 + \delta - f)}$ for $K(\pi)$ in the equation $\pi = 1 - K(\pi)$, multiplying through by $f + \pi(1 + \delta - f)$ and collecting terms we get that $\pi(r, f)$ must satisfy

$$(f - 1 - \delta)\pi^2 - [f - (1 + \delta - f) - (1 - t)r]\pi + f - t = 0.$$

This parabola equals $f - t$ at $\pi = 0$ and equals $-[t - (1 - t)r]$ at $\pi = 1$. Since $f \in [t, f_0]$, $f - t \geq 0$. Since $r < t/1 - t$, $-[t - (1 - t)r] < 0$. Thus, the parabola has a unique root in $[0, 1]$. ■

Proof of P3. Part (a): If $r \geq t/(1 - t)$, then from P2, $\pi(r, f) = 1$ and $b[\pi(r, f), r, f] \leq 0$. Thus, for all $a \in [0, 1]$, $a \geq b[\pi(r, f), r, f]$ and by P1, $\tau_a^* = 0$ for all a .

Part (b): If $r < t/(1-t)$, then $0 \leq 1 - \pi(r, f) = b[\pi(r, f), r, f] \leq 1$. Substituting into P1 yields the result. ■

Proof of P4. From G1's perspective, agent a chooses $\tau_a^* = 1$ iff $a < b_1(r)$, and $\tau_a^* = 0$ otherwise. Since $b_1(r) \leq 0$ for $r \geq t/(1-t)$, all agents are honest in this range. Because they are honest, they each pay full taxes $t(1+r)$. Since $b_1(r) \geq 1$ for $r \leq \frac{t-(1+\delta)}{1-t}$, all agents are thieves in this range. Because all agents are thieves, agent a is caught with probability a and pays $(1+\delta)$. Collectively, they pay $\int_0^1 a(1+\delta)dH = \frac{1+\delta}{2}$. For $\frac{t-(1+\delta)}{1-t} < r < t/(1-t)$, $0 < b_1(r) < 1$. Thus,

$$\begin{aligned} T_1(r) &= \int_0^1 a\tau_a^*(1+\delta)dH + \int_0^1 t(1-\tau_a^*)(1+r)dH \\ &= \int_0^{b_1(r)} a(1+\delta)dH + \int_{b_1(r)}^1 t(1+r)dH \\ &= \frac{(1+\delta)}{2}b_1^2(r) + t(1+r)[1-b_1(r)]. \blacksquare \end{aligned}$$

Proof of P5. r^* is the largest value of r satisfying $T_1(r) - C(r) = 0$. Thus, $T_1(r^*) - C(r^*) = 0$. The parameter θ ($\theta = \delta, t$, or f_0) appears in $T_1(r^*)$ in two ways, through r^* and directly through θ . The parameter θ appears in $C(r^*)$ through r^* only. Therefore, by differentiation, $T_{1r^*} \frac{dr^*}{d\theta} + T_{1\theta} - C_{r^*} \frac{dr^*}{d\theta} = 0$ or $(T_{1r^*} - C_{r^*}) \frac{dr^*}{d\theta} = -T_{1\theta}$. Since r^* is the largest r satisfying this equation, the slope of the cost function must exceed that of the tax revenue function at r^* . The result follows. ■

Proof of P6.

Part (a). For the left interval $r^* \leq \frac{t-(1+\delta)}{1-t}$, $T_1(r^*) = \frac{1+\delta}{2}$. Applying the result of P5, $\frac{dr^*}{d\delta} = 1/2$. For the middle interval $\frac{t-(1+\delta)}{1-t} \leq r^* \leq t/(1-t)$, $T_1(r^*) = \frac{(1+\delta)}{2}b_1^2(r^*) + t(1+r^*)[1-b_1(r^*)]$. Then, $T_{1\delta}(r^*) = \frac{b_1^2(r^*)}{2} + [(1+\delta)b_1(r^*) - t(1+r^*)]b_{1r^*}(r^*)$. Since

$b_1(r^*) = \frac{t-(1-t)r^*}{1+\delta}$, we have $T_{1\delta}(r^*) = \frac{1}{2}[\frac{t-(1-t)r^*}{1+\delta}]^2 - [t - (1-t)r^* - t(1+r^*)]\frac{t-(1-t)r^*}{(1+\delta)^2} = \frac{t-(1-t)r^*}{2(1+\delta)^2}[t - (1-t)r^* + 2r^*]$
 $= \frac{t-(1-t)r^*}{2(1+\delta)^2}[t + r^*(1+t)]$. Thus, $\frac{dr^*}{d\delta} < 0$ if $\frac{t-(1+\delta)}{1-t} \leq r^* < -t/(1+t)$ and $\frac{dr^*}{d\delta} \geq 0$ for $-t/(1+t) \leq r^* \leq t/(1-t)$. In the right interval, $r^* > t/(1-t)$, $T_1(r^*) = t(1+r^*)$ and $\frac{dr^*}{d\delta} = 0$. Thus, looking over all regions, $\frac{dr^*}{d\delta} < 0$ only if $\frac{t-(1+\delta)}{1-t} \leq r^* \leq -t(1+t)$ and part (a) follows.

Part (b). In the left interval $T_1(r^*) = \frac{(1+\delta)}{2}$ so $\frac{dr^*}{dt} = 0$. In the middle interval $T_{1t}(r^*) = (1+r^*)[(1-b_1(r^*)) + [(1+\delta)b_1(r^*) - t(1+r^*)]b_{1t}(r^*)]$
 $= \frac{1+r^*}{1+\delta}[1+\delta-t+(1-t)r^*] - [r^*]\frac{1+r^*}{1+\delta} = \frac{1+r^*}{1+\delta}[1+\delta-t(1+r^*)]$
 $= (1+r^*) - \frac{t}{1+\delta}(1+r^*)^2$. This quadratic is zero at $r^* = -1$ and at $r^* = \frac{1+\delta-t}{t}$ and is positive in between. Thus, $\frac{dr^*}{dt} \geq 0$ for r^* in $\{-1, \min[\frac{1+\delta-t}{t}, \frac{t}{1-t}]\}$ and is negative for r^* in $\{\frac{t-(1+\delta)}{1-t}, -1\}$. In the right interval $T_1(r^*) = t(1+r^*)$ so $\frac{dr^*}{dt} > 0$ here. Thus, over all regions, $\frac{dr^*}{dt} \geq 0$ everywhere except for $r^* \in \{\frac{t-(1+\delta)}{1-t}, -1\}$ and for $r^* \in \{\min[\frac{1+\delta-t}{t}, \frac{t}{1-t}]\}$. This establishes part (b).

Part (c) follows since r^* does not depend on f_0 .

Part (d) The first part of part (d) follows since f^* does not depend on t . If $f_0 \neq 1+\delta$, then f^* does not depend on δ and $\frac{df^*}{d\delta} = 0$. If $f_0 = 1+\delta$, then $\frac{df^*}{d\delta} = 1 > 0$ and part (d) follows.

Part (e) follows since $f^* = f_0$. ■

Proof of P7. The crime level $K^* = K^*[\pi^*, r^*, f^*, \theta]$ where $\theta = \delta, t$ or f_0 . Thus, $\frac{dK^*}{d\theta} = K_{\pi^*}^* \frac{d\pi^*}{d\theta} + K_{r^*}^* \frac{dr^*}{d\theta} + K_{f^*}^* \frac{df^*}{d\theta} + K_{\theta}$. As was shown in the proof of P2, for $r^* > t/(1-t)$, $b^* < 0$, and $K^* = 0$. It follows that when $r^* > t/(1-t)$, $\frac{dK^*}{d\theta} = 0$ for $\theta = \delta, t$ or f . We now consider the case when $r^* \leq t/(1-t)$. Since $\pi^* = 1 - K^*$, we have $\frac{d\pi^*}{d\theta} = -\frac{dK^*}{d\theta}$. Substituting this expression above, we have $(1 + K_{\pi^*}^*)\frac{dK^*}{d\theta} = K_{r^*}^* \frac{dr^*}{d\theta} + K_{f^*}^* \frac{df^*}{d\theta} + K_{\theta}^*$. As a result of our assumption that $H(a)$ is uniform, $K^* = b^*$, and the last expression can be written as $(1 + b_{\pi^*}^*)\frac{dK^*}{d\theta} = b_{r^*}^* \frac{dr^*}{d\theta} + b_{f^*}^* \frac{df^*}{d\theta} + b_{\theta}^*$. We first show that $(1 + b_{\pi^*}^*) > 0$. Since $f^* = f_0 \geq 1 + \delta$ and $r^* < t/(1-t)$, $1 + b_{\pi^*}^* = 1 + \frac{t(f^*-1-\delta)-f^*(1-t)r^*}{[f^*-\pi(f^*-1-\delta)]^2} \geq$

$1 + \frac{t(f^* - 1 - \delta) - f^*t}{[f^*]^2} = 1 - \frac{t(1 + \delta)}{[f^*]^2} > 0$. So we have that $\text{sign} \frac{dK^*}{d\theta} = \text{sign}[b_{r^*}^* \frac{dr^*}{d\theta} + b_{f^*}^* \frac{df^*}{d\theta} + b_\theta^*]$.

We use this expression in the following evaluations.

We first note that since $b^* = \frac{t - \pi^*(1-t)r^*}{f^*(1-\pi) + \pi^*(1+\delta)}$ it follows that $b_{r^*}^* < 0$, $b_{f^*}^* < 0$, and $b_\delta^* < 0$. Now let $\theta = \delta$. Then $\text{sign} \frac{dK^*}{d\theta} = \text{sign}[b_{r^*}^* \frac{dr^*}{d\delta} + b_{f^*}^* \frac{df^*}{d\delta} + b_\delta^*]$. Since $b_{r^*}^*$, $b_{f^*}^*$, and b_δ^* are all negative, all terms would be negative if $\frac{dr^*}{d\delta}$ and $\frac{df^*}{d\delta}$ are non-negative. From P6, $\frac{dr^*}{d\delta}$ is negative everywhere except for $r^* \in \{\frac{t-(1+\delta)}{1-t}, -\frac{t}{1-t}\}$ and $\frac{df^*}{d\delta}$ is non-negative everywhere. Thus part (a) follows.

Now let $\theta = t$. Then $\text{sign} \frac{dK^*}{dt} = \text{sign}[b_{r^*}^* \frac{dr^*}{dt} + b_{f^*}^* \frac{df^*}{dt} + b_t^*]$. From P6, we have $\frac{df^*}{dt} = 0$. Differentiating b^* with respect to t shows that b_t^* is a positive multiple of $1 + \pi^*r^*$ which is positive at $r^* = -1$ and since from P2, $\pi^* < 1$, there will exist an $r_0 < -1$ such that $1 + \pi^*r^* \geq 0$ for $r^* \geq r_0$. Since $b_{r^*}^* < 0$, $\frac{dK^*}{dt}$ will be positive where $\frac{dr^*}{dt} < 0$ and where $1 + \pi^*r^* \geq 0$. Using P6, part (b) follows.

Finally, let $\theta = f_0$. From P6, $\frac{dr^*}{df_0} = 0$ and b^* does not explicitly depend on f_0 . Furthermore, both $\frac{df^*}{df_0} > 0$ and $b_{f^*}^* < 0$, thus $\text{sign} \frac{dK^*}{df_0} < 0$. ■

Proof of P8. As was shown in the text, $F = \frac{1-(1-K^*)^2}{2}$ when $b^* > 0$ and 0 otherwise. As argued in the proof of P2, $b^* > 0$ if $r^* < t/(1-t)$ and is negative otherwise. So

$$F = \begin{cases} 0 & \text{if } r^* \geq t/(1-t) \\ \frac{1-(1-K^*)^2}{2} & \text{if } r^* < t/(1-t) \end{cases}.$$

Differentiation with respect to θ , $\theta = \delta, t$ or f_0 yields the result. ■

Proof of P9. From P8, we have that $\text{sign} \frac{dF}{d\theta} = \text{sign} \frac{dK^*}{d\theta}$. Using P7, the result follows. ■

5. References

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