

## CORRUPTION, COOPERATION AND ENDOGENOUS TIME DISCOUNT RATES

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### Abstract

Virtually all uses of repeated games to study of cooperation assume that people's time discount rates are exogenous and fixed. Here we offer an evolutionary game embedded in a multi-period model of investment and consumption in which individual time discounts are determined by their convergence to values determined by Evolutionary Stable Strategies. Our substantive motivation, though, is corruption and its relationship to economic growth. To understand the observed relationship between levels of corruption and economic indicators of social welfare, we argue that corruption is a form of cooperation that requires close interpersonal monitoring. If we assume, moreover, that when people discount the future greatly the only sustainable forms of cooperation are those that allow for close monitoring, then our analysis can be interpreted as a dynamic model of the relationship between corruption and investment.

### Corruption, Cooperation and Endogenous Time Discount Rates

Corruption, however defined and regardless of whether its manifestations are primarily economic or political, is unquestionably damaging to society's economic development. Despite speculation that it facilitates certain types of economic exchange, there is scant evidence that on net corruption encourages much of anything except slower economic growth, under-investment, capital flight, and a general malaise with respect to the legitimacy of political institutions. Unsurprisingly, a considerable literature has developed to understand corruption in its various guises, to measure its economic impact, and to offer practical guidance for its minimization, especially in those societies with market institutions that are in the initial stages of development. Despite this research and despite the countless economists, lawyers, political scientists, and sociologists who seemed to travel daily from London, Paris, Bonn, and Washington D.C. to Moscow, Kiev and points east, corruption is now seen as endemic to most of the states of the former Soviet Union. Ten-plus years of economic, political, and legal advice about how to proceed with democratic reform, privatization, and economic development have not averted the emergence of regimes that are democratic only by the most forgiving definitions, whose legal systems are barely observable, and whose political-economic processes seem to have been captured by criminal syndicates, ravenous public bureaucracies, and a cadre of elected elites whose primary interest is little more than a chance to feast at the public trough.<sup>1</sup>

A broad range of the empirical correlates are cited as corruption's 'cause': an underdeveloped legal code, a weak state, the absence of firm guarantees of private property, a tradition of public acceptance, and corruption itself as when the inefficiencies it generates increase the benefits or decrease the costs of its expansion. In the case of the former Soviet Union, fingers also point at the faulty means by which the state's assets were privatized, a constitution that gives representative institutions too little power and chief executives too much, a judiciary ill-equipped to enforce its decisions, and the natural extension of social practice learned during a communist era, including a failure to appreciate the concept and defense of private property. However, when treating a concept with a variety of empirical manifestations and which appears to impact or infect all aspects of social process, one suspects that the 'causes' cited, whether general or specific to one society or another, are not true causes in any scientific sense. That is, the 'causes' cited are neither necessary nor sufficient, and more often than not they are both a consequence of the phenomenon under investigation as well as its antecedent.<sup>2</sup> What, for example, is the proper direction of the causal arrow connecting corruption to a weak state? Certainly it is reasonable to assume that a state unable to defend property rights facilitates theft of both private and public resources. On the other hand, we can also imagine political corruption acting as an impediment to reform by the motive it gives political elites to use their positions for private gain. In this instance corruption is as much a cause as a consequence. Similarly, although it is reasonable to assume that corruption increases transaction costs for potential investors and thus leads to under-investment and slow growth, we can also argue that corruption is an 'inferior' good and that the demand for it increases when incomes and public resources decline. In this instance actions deemed to be corrupt are a substitute for other actions whose relative productivity declines whenever public and private resources shrink. And here we see a spiraling simultaneity: corruption inducing stagnation which in turn induces still more corruption.

It is this simultaneity that we try to disentangle by stepping back from specific empirical manifestations in order to conceptualize corruption as a form of cooperation, albeit a type we might prefer not to see in markets, so that we can look more closely at the different mechanisms of contract enforcement. We note in particular that regardless of whether one's analysis of cooperation and enforcement begins with scenarios such as the prisoners' dilemma, some model of principle-agent relations, a theory of credible threats, or more generally one of game theory's folk theorems, a critical parameter is the discount rate people apply to the future. In all such analyses, however, that rate is exogenous — a fixed parameter that does not vary as a function of anything in the model under consideration: «rates of time preference are almost invariably taken as 'given' or exogenous, with little discussion of what determines their level» (Becker and Mulligan 1997: 729). The particular innovation we offer here is a model in which time discounts are endogenous — a product of an evolutionary adaptation to people's interactions in the market. That model, in turn, is embedded in a model of optimal investment whereby time discounts effect people's consumption/investment decisions, and in this way, evolving time discounts impact society's net capital, which serves as one measure of social welfare. In Section 1, then, we examine more closely the connection between time discounts and corruption, arguing that the forms of cooperation we are likely to see when discounts are high are more consonant with corrupt exchanges. Section 2 offers a formalization of investment and endogenous discounts that consists of a model of optimal investment and an embedded evolutionary game that dictates change in discount rates. In Section 3 we consider this model's varied implications, including the impact on private investment and consumption of market rates of return, the initial distribution of private discount rates, the pace of evolutionary change in these rates, and regimes that differ in the degree to which they protect private investment. Section 4 concludes this essay with some general observations about alternative models and the implications of our research for the analysis of cooperation and corruption generally.

## 1. Corruption as Cooperation

Empirical research alone is unlikely to untangle the causal nexus linking measures of corruption to its social correlates, if only because of the complexity of the phenomena under investigation. At the same time, models that map observed interconnections with mathematical rigor are equally unlikely to resolve issues of cause and effect since those models by their very nature presume specific causes in their structures. In this essay, then, we step back from corruption's observed manifestations and formal treatments of its proximate 'causes', and look at the phenomena as a form of cooperative behavior, albeit a different form than what we associate with 'normal' (idealized?) market process.

To begin, notice that corruption requires cooperation. In its most common form, an instance of corruption requires an exchange — money for services, or services for services — that, ostensibly, the law either doesn't or shouldn't allow. However, regardless of whether we deem a particular exchange an instance of corruption, perhaps the most theoretically interesting aspect of cooperation are the mechanisms people employ to enforce agreements and the particulars of a cooperative exchange. The specific practical problem with which cooperation of any type must contend is that few examples of exchange allow for an instantaneous event. If, for example, money is paid for a service, that service is either performed before the full cash value is exchanged or it is performed subsequently. In either case, whoever moves second has an incentive to defect and renege on their side of the bargain. Efficient exchange, then, requires an enforcement mechanism that ensures against or at least discourages defection: «although cooperation produces mutual gains for those who participate, in the absence of an enforcement mechanism cooperation will not be possible» (Posner 2000: 13).

Insofar as the mechanisms we might see in practice that allow enforcement, there are, of course, the courts and the remedies the judicial process establishes. Second, there are those social norms that try to enforce notions of justice and fair exchange through informal sanctions and the value people place on their reputations for fairness and honesty. Here enforcement takes the form of a refusal to deal subsequently with a person who has been judged untrustworthy in the past. And finally there is simply force, applied either by the state or by people individually. Thus, regardless of substantive form, these mechanisms all imply a threat -- the threat of future sanction or future reward. However, to be effective, threats require three things: monitoring, credibility, and people who do not discount the future 'too greatly.' First, it must be possible to monitor a person's actions so that those party to the exchange can discriminate between a defection and compliance. It may be the case that monitoring is imperfect and that only indicators can be employed as when a person is a member of some large group (e.g., a work group) and only the product of the group's combined effort is observable. In this instance, sanctioning threats may have to be applied against every member of the group or to some member chosen randomly. But the principle is the same: monitoring allows a defection today to be punished tomorrow. The second thing required for effectiveness, is that implementing a threat or promise must correspond to a subgame perfect equilibrium in the game that describes the participant's circumstances. That is, whoever is empowered to administer, say, a punishment in the event of a defection must find it in their self-interest to apply the appropriate sanction. Absent this, there cannot be an agreement since the contracting parties know that whoever moves second will have little incentive to hold up their end of the bargain. Finally, the threat must deter defection, which requires that the potential defector cares sufficiently about the

future that he or she will forego any potential immediate gain from defection in order to avoid the threat of future loss or to realize the promise of future gain.

The effectiveness of a threat is critical to sustaining cooperation even when it entails nothing more costly than a damaged reputation and a refusal by others to cooperate with the defector in the future. But having placed responsibility for cooperation on credible threats and promises, it is useful to briefly examine the requirements for their effectiveness and the role of monitoring, and here we can consider the classic illustration of the problem of cooperation, the repeated prisoners' dilemma.

	Cooperate	Defect
Cooperate	1, 1	-2, $K$
Defect	$K$ , -2	0, 0

The game in this table is a prisoners' dilemma provided only that  $K$  exceed 1, in which case Defect is a dominant strategy and the unique equilibrium outcome is (0,0). Now, however, consider an especially simple repeated form of this game that allows only two strategies: (D) defect always; and (GT) a grim-trigger strategy that chooses C as long as the 'opponent' cooperates, but which switches to D for all time upon the detection of a single defection. Rather than analyze this situation by simply letting  $d$  be the discount factor a person applies to future payoffs, suppose detection is uncertain: specifically, let  $q$  be the probability of detecting a defection. Hence, if a person defects to D when their opponent plays GT, then they get a payoff of  $K$  for one period, a payoff of zero thereafter with probability  $q$  (the probability their defection is detected and they are punished in all future rounds), and a chance to take advantage of the opponent in the next round with probability  $1-q$ . Thus, the discounted value of defecting to D when played against GT is:

$$K + Kd(1-q) + Kd^2(1-q)^2 + Kd^3(1-q)^3 + \dots = K/[1-d(1-q)]$$

so that the repeated game in strategic form becomes:

	GT: grim trigger	Defect always
Grim Trigger	$1/1-d, 1/1-d$	$-2/[1-d(1-q)], K/[1-d(1-q)]$
Defect always	$K/[1-d(1-q)], -2/[1-d(1-q)]$	0, 0

Notice now that the strategy pair (GT,GT), which uniquely yields cooperation in this limited version of the repeated dilemma, is an equilibrium if and only if  $1/(1-d) > K/[1-d(1-q)]$ , or, equivalently, if

$$d > (K - 1)/(K - 1 + q)(1)$$

Thus, if detection is certain ( $q = 1$ ), we have the usual condition for a cooperative equilibrium,  $d > (K - 1)/K$ . That is, the 'shadow of the future' must be sufficiently great so that the cost of future punishments outweighs the short term gains from defection. Conversely, if  $q = 0$ , cooperation is impossible. For intermediate cases, Figure 1 plots expression 1 for various values of  $K > 1$  so that (GT,GT) is an equilibrium for any value of  $(d, q)$  above the line corresponding to the chosen value of  $K$ , and (D,D) is the unique equilibrium for any value below the line.

The implications of this figure are intuitive. First, as  $K$  increases — as the relative value of defection increases — the requirement on  $q$  and  $d$  for cooperation become more severe. And second, as monitoring becomes more difficult (as  $q$  decreases), the value of  $d$  required to sustain cooperation increases. Alternatively, we can say that *as the weight given to the future,  $d$ , decreases, cooperation will be sustained in only those exchanges in which monitoring is near-perfect*. Of course, there is nothing exceptional about this analysis. We can readily substitute a cost of monitoring for  $q$ , or allow a more complex array of strategies that permit punishments in various forms (e.g., tit-for-tat or grim trigger strategies that punish for a prespecified number of rounds), but the substance of our conclusions remains unchanged.<sup>3</sup>

Our task now is to establish the relevance of this analysis to corruption, and here it is useful to consider the fact that corruption, especially its political forms, commonly entails a bilateral or small-scale relation — between, for instance, the bribe giver and the bribe taker or between a bribe giver, an agent for the bribe taker (e.g., a bureaucrat who acts as an agent from some higher level official with the authority to deliver on a promise), and the bribe taker. Scale is dictated here by the fact that owing to the ostensible illegality of the exchange, a certain amount of secrecy is required. Indeed, absent a legal system to enforce contracts and often little more than social acquiescence rather than adherence to social norms as an alternative to the courts, «gift giving and bribery will be more common if legal dispute resolution mechanisms are costly and time consuming. If legal guarantees are not possible, trust is correspondingly more important [and] ... both sides to the

deal have an interest in blurring the meaning of the payment in the eyes of the outside world while keeping it quite explicit between themselves.» (Rose-Ackerman 1999: 98).

But trust is based on reputation — «unless there are repeated transactions, how is an official to guarantee performance or a payee to guarantee payment if the service is provided prior to payment?» (Jain 2001: 90) — which, if secrecy is to be maintained, requires a more atomistic and less anonymous form of exchange than the forms of market cooperation we assume correspond to, say, international investments or corporate finance. Corrupt officials simply do not have the luxury of establishing a brand label — a reputation for fulfilling their corrupt obligations — in the same way a manufacturer of baby food might seek to develop a reputation for a safe and nutritious product: «How can an official announce that he or she is willing to enter a corrupt deal? While open dissemination of this information would attract the best buyer, it would also attract attention from controlling authorities and rivals or superiors who might wish to share in the proceeds.» (Jain 2001: 90). Put differently, «Because legal advertising and official certification are out, corrupt officials need to communicate by other means. The difficulty of establishing a reputation may lead crooks to deal only with known partners ... Establishing a corrupt relationship between strangers is risky because the first one who is explicit about wanting to make or accept a payoff is at the mercy of the others who can threaten to report the illegal act ... Stable corrupt systems will be easier to maintain in small, local markets than in large national or international ones» (Rose-Ackerman 1999: 101).

This is not to say that all 'atomistic' forms of cooperation are necessarily corrupt: witness the role of reputation in private exchanges between repeat customers and, say, a neighborhood grocery store (for elaboration of this argument see Posner 2000). However, what we are saying is that if cooperation requires close monitoring, and if corrupt forms of cooperation are necessarily atomistic, then, *ceteris paribus*, the more atomistic the exchange necessitated by the requirements of monitoring, the more likely are those exchanges to fall into the category of cooperation we call corruption. And if this assumption is correct, then Figure 1 is itself an argument for inferring that as people's time discounts increase — as  $(1-d)$  increases — the forms of cooperation we observe will more likely correspond to corruption. That is, as  $(1-d)$  increases, the cooperation we see will more likely require closer and more perfect mechanisms of monitoring, which, in turn, will tend to drive out of the political-economic market those forms of cooperation that rely on impersonal and judicial modes of monitoring, leaving in place and even encouraging those forms, including corruption, that can be sustained by trust and close interpersonal relations.

Of course, the *ceteris paribus* condition of the preceding argument is important. As Yamagishi, Cook and Watabe (1998) argue, non-corrupt cooperation can also predominate in social systems that rely on close interpersonal relations. Nevertheless, the preceding argument does rationalize the view that if people give the future little weight, their actions will more likely correspond to the rule 'get what you can while the getting is good,' which, in turn, seems more suitable to an economy driven by corrupt business and political practices and short-term objectives rather than the long term investment criteria often employed when evaluating a more standard business venture. Our argument here, then, is in accord with those formal treatments of corrupt exchange that treat time discounts as exogenous, to wit: in equilibrium, «the number of corrupt bureaucrats is higher ... the higher the discount rate» (Andvig and Moene 1990: 68). And although our argument differs somewhat, we nevertheless concur with view that «corrupt officials may well have a higher discount rate than the country's citizens. Even a ruler who has good short-term control over society may not have secure long-term tenure. The ruler's very venality may make him insecure and subject to overthrow. This insecurity induces him to steal more, making him even more insecure, and so forth. As a consequence he or she will have a relatively high discount rate for government projects and will support projects with quick short-term payoffs and costs spread far into the future.»<sup>4</sup> Here, then, discount rates as a determinant of the forms of cooperation one is likely to see, becomes an important determinant of society's level of corruption — and, ultimately, its efficiency and productivity.

## 2. The Endogeneity of $d$

Regardless of whether one accepts our formalization of Rose-Ackerman's inferred conjecture, what is interesting about the preceding conclusion concerning the effect of time discount rates on corruption is that economic theories of cooperation as well as economic models of cooperation uniformly assume that private valuations of time are fixed and exogenously determined.<sup>5</sup> This assumption, however, seems untenable, and its modification may hold the key to understanding such phenomena as changes in the level of corruption over time in a society, variations in that level across societies, and the impact of corruption on economic performance.<sup>6</sup> First, consider this argument: 'If everyone or nearly everyone in society places a low value on the future, then a person would be a fool to act otherwise — to act with a long-term planning horizon.' Alternatively, 'if I believe that everyone or nearly everyone will take advantage of me by failing to fulfill the terms of a contract unless the sanctions I can impose are large and detection certain, then it would be irrational to act as if I held a long term planning horizon and assumed that the terms of exchange would necessarily be honored as a matter of course.' Such arguments suggest a dynamic in which corruption feeds on itself via its impact on people's valuations of the future.<sup>7</sup> Indeed, it may be more reasonable to conceptualize people as if they operated with a variety of

time discounts: long-term for easily monitored relationships and short-term for less easily monitored exchanges, notably those that occur outside the sphere of their immediate social connections. As the external environment grows more risky so that operating with a limited planning horizon becomes a necessity in this sphere, people come to rely more on those relationship that allow for long term commitments and exchanges, which, if our earlier argument is correct, implies substituting exchanges that might be deemed instances of corruption at the expense of those less-personal and more anomous exchanges that characterize markets elsewhere.

**An Investment Model:** To address these issues, we begin with a simple model of investment and growth in which there are  $N = \{1, 2, \dots, n\}$  persons, each endowed initially with  $K_0$  units of resources. Each person also begins by holding either one of two time discount factors,  $d = d_{high}$  and  $d = d_{low}$  such that  $0 < d_{low} < d_{high} < 1$ . In the initial period  $t = 0$ , each person  $j$  in  $N$  must choose an allocation of their initial endowment  $K_0$  between immediate consumption,  $C_0$ , and investment,  $I_0$ , which produces future resources for consumption and investment. Immediately after investment, each person is assumed to participate in a game  $G_t$  which determines  $j$ 's actual consumption payoff and the personal discount rate that 'survives' into the next period. We describe this game in detail shortly, using it to model alternative evolutionary processes in the market, depending on our conceptualization of corruption and social interaction. For now, however, we assume simply that every unit of resources 'spent' on consumption yields one unit of value. We assume in addition that all persons in  $N$  play the same game  $G$  though all periods, and in any period  $t$ , each person assumes, for purposes of making their investment/consumption decision, that all periods which follow ... all games to be played in the future ... have the same characteristics of the most recently played game in period  $t-1$ .

Before describing the game people play in consumption, let us consider the model of investment and consumption in which  $G$  is imbedded. Dropping the subscript  $j$  for convenience, consider a situation in which investment yields a one period return of  $r$ , so that  $X$  invested in period  $t$  yields  $(1+r)X$  in period  $t+1$ . Let  $C_0$  and  $I_0$  be a person's consumption and investment in the initial period ( $t = 0$ ), so that in period  $t=1$  they must divide  $(1+r)I_0$  between period 1 consumption and investment. Let that decision be  $C_1$  and  $I_1$  respectively, where  $C_1 + I_1 = (1+r)I_0$ . Similarly, in period  $t = 2$ , that person must then allocate  $(1+r)I_1$  in a similar fashion between  $C_2$  and  $I_2$ , where  $C_2 + I_2 = (1+r)I_1$ , and so on. Since we are concerned with the steady state of this scenario, we make the simplifying assumption that this state is reached at  $t = 1$  (and given the simplicity of our model, this is a feasible consumption/investment path). Thus,  $C^*_1 = C^*_2 = C^*_3 = \dots$  etc. In period 0, then, a person foresees (perhaps incorrectly) the present value of his consumption stream as

$$\begin{aligned} C^*_0 + dC^*_1 + d^2C^*_1 + d^3C^*_2 + \dots = \\ C^*_0 + C^*_1 - C^*_1 + dC^*_1 + d^2C^*_1 + d^3C^*_2 + \dots = C^*_0 - C^*_1 + C^*_1/(1-d) = \\ C^*_0 + dC^*_1/(1-d). \end{aligned} \quad (2)$$

If utility is linear, expression (2) describes what  $j$  maximizes when making an initial investment-consumption decision. This is not necessarily what  $j$  experiences since his assumptions about the game  $G$  may be (and generally will be) erroneous, but this is the function that dictates a person's initial decision. We can, then, solve for the maximum pattern of investment by observing that at steady state, if  $K_0 - C_0$  is invested in period 0, the period 1 'budget' is

$$K_1 = (1+r)(K_0 - C_0).$$

Thus, in period 1, if he consumes  $C_1$ , then he invests  $(1+r)(K_0 - C_0) - C_1$ , which yields

$$(1+r)[(1+r)(K_0 - C_0) - C_1]$$

to be allocated in period  $t = 2$ . But since we are describing a steady state, a person will assume in his initial plans that he will again consume  $C_2 = C_1$  and invest

$$(1+r)[(1+r)(K_0 - C_0) - C_1] - C_1.$$

It also follows that this quantity, the amount invested in period 2, must equal the amount invested in period 1. Thus,

$$(1+r)(K_0 - C_0) - C_0 = (1+r)[(1+r)(K_0 - C_0) - C_1] - C_1.$$

Simple algebraic manipulation reduces this equation to  $C_1 = R(K_0 - C_0)$ . Substituting this identity into equation (2) gives

$$C_0(1 - d - dr) + drK_0 \quad (3)$$

as the thing a person maximizes by an appropriate selection of  $C_0$  (and, from expression (3), of  $C_1$ , etc.). But notice that (3) is linear in  $C_0$ , so if  $(1 - d - dr) > 0$ , the stream of utility, as perceived in period 0, is maximized by setting  $C_0$  at the maximum,  $K_0$ , leaving nothing for the future; but if  $(1 - d - dr) \leq 0$ , the stream of utility is maximized by setting  $C_0$  at the minimum, 0, so that all consumption lies in the future in accordance with expression (2). In summary, if  $0 < (1 - d - dr) > 0$ , the person's anticipated stream of consumption takes the form  $(K_0, 0, 0, \dots)$ , but if  $(1 - d - dr) \leq 0$ , then the anticipated stream takes the form  $(0, rK_0, rK_0, \dots)$ .<sup>8</sup>

There is one fact to be noted about this model that follows from its linear structure and which is especially useful in our analysis. Notice that if we award people with an exogenously supplied supplemental income in each period, say  $k$ , so that low  $d$ 's do not disappear from the analysis, all investment-consumption decisions with respect to endowments are unchanged: High  $d$ 's invest  $K + k$  rather than simply  $K$ , their return on investment from the prior period, whereas low  $d$ 's consume all of  $k$  rather than 0, and the impact of other parameters is unaffected.

**The Game G:** Our interest here is not in the overall patterns of investment versus consumption, and indeed more complex and more traditional models of optimal economic investment can be substituted for the simple one we present. Instead, our focus is to model a process whereby private discount rates change as a function of a person's experiences in the market. There are, admittedly, a great many ways to proceed, and what we want to do is explore an especially promising possibility that employs evolutionary game theory. Suppose, then, that a person confronts the game  $G$  in each consumption period and suppose that the 'extent of a person's involvement' in the market is strictly proportional to his or her consumption. Each person's weight in the market, then, is proportion to his or her level of consumption. Next, suppose that when two people 'meet', they are in effect, playing an evolutionary game in which: (1) if two 'high d's' meet, they engage in a mutually beneficial exchange that yields each of them a payoff of 1; (2) if two 'low d' people meet, they try to cheat each other (owing to the low value they place on the future) and thereby realize a payoff of 0; and, (3) if a high d and low d meet, their respective payoffs are the parameters  $-v$  and  $u$ . Thus, the structure of payoffs is as follows:

	high d	low d
high d	$1, 1$	$-v, u$
low d	$u, -v$	$0, 0$

The payoffs  $u$  and  $v$  can be used to model a variety of situations. If  $u > 1$  and  $v > 0$ , the game is a Prisoners' Dilemma; if  $u > 1$   $v < 0$ , then the situation corresponds to the game of Chicken; and if  $u > 1$  and  $v < -1$ , the situation is a Battle of the Sexes. However, rather than treat this payoff structure as a two person game, we instead want to use it as a model of an evolutionary process in which cell payoffs correspond to 'fitness'.<sup>9</sup> The ESS here is, of course, a function of the parameters  $u$  and  $v$ . Specifically,

- if  $u > 1$  and  $v > 0$ , the unique Nash Equilibrium is  $(0,0)$ , so the unique ESS is «all low d's».<sup>10</sup> That is, a population that contains any high d's will evolve to one that contains only low d's.
- if  $u < 1$  and  $v < 0$ ,  $(1,1)$  is the unique Nash Equilibrium; and unique ESS is 'all high d's',
- if  $u > 1$  and  $v < 0$ , there are two pure strategy Nash Equilibria,  $(u, -v)$  and  $(-v, u)$ , and one mixed strategy equilibrium ( $q = -v/(u-1-v)$ ,  $(1-q) = (u-1)/(u-1-v)$ ).<sup>11</sup> However, only the mixed strategy is ESS. The population is polymorphic and allows for low and high d's.
- if  $u < 1$  and  $v > 0$ , both  $(1,1)$  and  $(0,0)$  are Nash Equilibria, but only  $(0,0)$  is ESS.

Now suppose that in playing this evolutionary game, each player  $j$  in  $N$  is given the weight  $C^*_{jt}$  in period  $t$ , which we take to mean that the game will be analyzed 'as if' there are  $C^*_{t1} + C^*_{t2} + C^*_{t3} + \dots + C^*_{tm}$  players. This determines the proportion of 'high d' and 'low d' types, with the corresponding ESS determining the mix that proceeds to the next period,  $t+1$ . There are now only three possibilities: (1) «All high d» is ESS, and all low d's become high d's; (2) «All low d» is ESS, and all high d's become low d's, and; (3) A mixture is ESS, in which case the population moves in the direction of the corresponding ESS proportions.<sup>12</sup> For case 1, unless low d's receive a supplemental income, they will all disappear. For case 2, all high d's will disappear and the return on their investment will be given to the transformed low d's. And unless there is a supplemental income, the process will terminate with everyone consuming all resources in the next period. Finally, for case 3, either some low d's must become high d's or some high d's must become low d's (with the resources of transformed players being carried with them) so as to satisfy the proportions dictated by the ESS.

In our actual analysis we allow for the possibility that adjustments occur incrementally — that not all high or low d's transform themselves immediately if the ESS dictates change. Indeed, this adjustment rate proves later to be one of the critical parameters of our analysis. But before proceeding, we should comment on the general approach taken here and the reasonableness of an ESS model. At issue is what it is that evolves in our evolutionary interpretation, since we are not so bold as to assume that people with high or low discounts literally die out in the process we describe. If that were true, it would be difficult to use this model to account for the apparent rapid changes in corruption we observe in say Russia or Ukraine — changes that appear to have required less than a decade to reach fruition. Here, then, we can appeal to Dawkins's (1976) notion of a *meme*, which he describes thus: «Just as genes propagate themselves in the gene pool by leaping from body to body via sperms or eggs, so memes propagate themselves in the meme pool by leaping from brain to brain via a process which, in the broad sense, can be called imitation» (p. 192) wherein «selection favors memes that exploit their cultural environment to their own advantage» (p. 199). The idea here, then, is that private discount rates are like memes and can change within a person's head, depending on his or her experience in the market. If holding a high discount proves especially advantageous, then either incrementally or instantaneously, that person will switch to making decisions in

accordance with the advantaged rate. We have here, then, a process like learning, except that a specific model of learning is subsumed in the notion of ESS and the values we give to  $u$  and  $v$  in  $G$ . If, for instance,  $u > 1$  and  $-v < 0$ , then it is obviously the case that there is an advantage of some type to discounting the future heavily (d low) as opposed to discounting it slightly (d high) when opposite types meet, whereas if  $v < -2$ , then those who act in accordance with having a high d's can take advantage of those who discount the future heavily. To illustrate, then, the process envisioned by our analysis:

- If  $K_h$  denotes the resources controlled by all high d's, and  $K_l$  the resources of all low d's, then the share of resources consumed by high d's is  $rK_h$ , whereas that consumed by low d's is  $K_l$  (if  $1 - d_{low} - rd_{low} > 0$ ) or  $rK_l$  (if  $1 - d_{low} - rd_{low} < 0$ ). For purposes of this illustrative discussion suppose low d's consume everything and invest nothing.
- proceeding to the game  $G$ , let the ESS dictate a mix between high and low d's of  $(1-p)$  and  $p$  respectively, with  $0 < p < 1$ . However, the proportion of high d's represented in the market is unlikely to correspond precisely to this proportion. Suppose the actual mix in consumption is  $(1-q)$  and  $q$  respectively, where  $q < p$ . Hence, there must be an adjustment in which the proportion  $p-q$  is transformed from high to low d. The adjustment can be immediate or incremental, depending on the setting of parameters,
- Low d's have not earned anything since they invested nothing, whereas high d's earned  $(1+r)(1-r)K_h$ . But this return must be shared with low d's in the next round since some previously high d's have been transformed. In particular, low d's will enter the next period with  $(p-q)(1+r)(1-r)K_h + pnk$  — the resources gained from the high d's plus their share of the supplemental income — and high d's will control  $(1-p+q)(1+r)(1-r)K_h + (1-p)nk$ .<sup>13</sup>
- all persons make new investment/consumption decisions and the process repeats itself.

There are several questions awaiting answers now, including: If there is a stable population, what is the relationship between the proportion of, say, high d's and the parameters of the model, including the market return on investments ( $r$ ), the rate of incremental adjustment ( $ar$ ), the initial distribution of resources across types, the supplemental income ( $k$ ), and the proportion of low d's ( $p$ ) implied by the variables  $u$  and  $v$ ; and how do steady state investments compare to what we might observe if everyone is a high d and remain thus? In other words, what are the social costs of corruption as it is modeled here in terms of people who discount the future heavily?

### 3. Analysis

Owing to the complexity and number of parameters in our model, we forego closed form analytic results in favor of a computer generated assessment. Briefly, then, Figure 2 graphs total invested capital against 'time' and illustrates convergence to an equilibrium for various values of  $p$ , the ESS proportion of low d types, when supplemental income,  $k$ , equals .2,  $r$  equals .05, the initial proportion of low d's is zero, and we allow an incremental adjustment rate of ten percent.<sup>14</sup> A more interesting way to view this data, however, is to look at the equilibrium value of investment plotted against  $p$  as in Figure 3. As expected, we see that as the ESS value of  $p$  increases, total investment decreases. However, the rate of decline is especially pronounced when  $p$  is low. That is, an initial increase in the proportion of the population above zero of those who value the future slightly and, thereby, consume everything, has a disproportionate impact on total invested capital. *If one accepts, then, our argument linking valuations of the future with corruption, the implication of Figure 3 is that the initial stages of the expansion of corruption are especially critical to society's overall level of invested capital.*

Although this result may be intuitive,  $p$ 's impact on total consumption is less obvious, since there are countervailing forces here. Although high d types invest, we might speculate that they invest so much that although total investment increases, consumption declines. Indeed, letting investment be our sole criterion of welfare ignores the fact that a society which invests everything is a society that consumes nothing. Figure 4, then, graphs total consumption against time for the same adjustment rate (.1) and values of  $p$  as in Figures 2 and 3, and reveals that consumption does in fact increase as  $p$  declines. The initial stages of this increase, however, exhibit an interesting pattern. As Figure 5 shows in detail, initial periods are marked by greater consumption when  $p$  is high. It is only later, when the investments of high d types allow them to consume more, that societies with fewer low d types in equilibrium consume more overall. Here, then, it is tempting to draw a parallel to the excesses of consumption reported among 'new Russians,' whereby a burst of consumption for luxury goods, often at inflated prices, seems to characterize anyone who finds a way to benefit from the initial emergence of a market economy.

Our next two figures, 6 and 7, show the impact of  $r$  on both total investment and consumption. Here our intuition is less secure since there are at least two opposing forces: First, as  $r$  increases, the return on investment increases, but, second, any increase in  $r$  also implies an increase in the rate of consumption among high d types. Thus, although Figure 6 shows that any increase in consumption owing to higher values of  $r$  is not so great as to eat into the social gains from investment,

we need to ask again whether this increase in social capital implies a corresponding increase in consumption or is consumption declining at the expense of investment. Figure 7 answers this question, but not in a simple way. Although the *equilibrium steady state* value of consumption is greater when consumption is 'suppressed' by low values of  $r$ , paralleling what we found when varying  $p$ , consumption is initially greatest for high values of  $r$ . Again we are reminded of the seemingly excessive consumption and absence of investment that characterized behavior in Russia despite the rates of return offered by private banks and the government that often exceeded 300%. These rates, of course, were the consequence of Russia's uncertain history with respect to public and private finance and a corresponding lack of faith in the government and private sector; but, as in Figure 7, these rates resulted in neither high savings (except for capital moved offshore) nor significant domestic investment.

Figures 8 and 9 offer a final assessment of the impact of two other parameters. Setting the adjustment rate at .2, Figure 8 shows the impact of choosing different values for the initial percentage of low  $d$ 's in the population, and the effect here is as expected and inconsequential — an initial low ESS value of  $p$  yields greater initial investment, but the eventual steady state equilibrium is unaffected. In contrast, as Figure 9 shows, the impact of the adjustment rate  $ar$  is neither intuitive nor inconsequential. Specifically, the lower the value of  $ar$ , the greater is the overall steady state level of savings, although for 'very low' values (i.e.,  $ar = .05, .1$  and  $.15$ ) those levels are approximately the same. The explanation for this dependence appears to be this: If the proportion of low  $d$ 's is allowed to increase only slowly from 0, high  $d$ 's have an opportunity to save and earn on their investments. The share of high  $d$ 's that need to be transformed to low  $d$ 's in accordance with  $p$ , then, is reduced, since when transformed they bring with them their savings, which then become consumption — thereby allowing the share of consumption attributable to low  $d$ 's to approach  $p$  without requiring a corresponding increase in the actual proportion of low  $d$ 's in the population. Thus, a lower incremental rate of adjustment allows for a larger share of the population to remain high  $d$  types in equilibrium.

Again it is tempting to speculate about the substantive meaning of this result. Among other things, it suggests that one 'solution' to low investment and increasing corruption in an emerging market economy is not to attempt to 'stamp out' corruption, but to slow its rate of increase. Potential investors who have confidence in and value the future must be allowed to make their investments and dominate the market. Of course, we might speculate that a rapid adjustment rate is best if there is an initial excessive share of low  $d$ 's (relative to the ESS value of  $p$ ). However, as Figure 10 shows, although an excessive initial share and high adjustment rates yield a slightly greater level of social capital in the initial periods, eventually the investments that high  $d$ 's are allowed to make over time when adjustment rates are low increases social capital above these numbers, so that once again a slower rate of adjustment is best — at least here in the long run.

There is now one final assessment to be made. To this point we assume that the market rate of return,  $r$ , is exogenous and fixed, which is reasonable if we assume that  $r$  is determined by external market forces. But if there is theft — illegal (in the form of massive corruption) or legal (in the form of a socialist regime that threatens private property) — such that investments and their returns must be shared generally, then the effective rate for those who invest is less than  $r$  — perhaps even negative. In this case, investments will continue to earn at the rate  $r$ , but investors will allocate their resources between consumption and investment on the basis of an implicit rate  $r' < r$ . Taking an extreme case in which savings are shared with certainty, suppose the proportion of the population that invests is  $1-p'$  but that savings are shared in the next period with everyone. Hence, an investor who invests  $X$  will only realize  $(1-p')(1+r)X$ , assuming that all investors are identical and all non-investors identical. Then to solve for  $r'$  we set  $(1+r')X = (1-p')(1+r)X$ , in which case  $r' = (1-p')(1+r) - 1$ . If we assume, now, that if  $r' < 0$ , then an 'investor' simply consumes everything at his or her disposal — why save when returns are negative? Of course, we could solve immediately for the point at which all savings disappear if  $p'$  simply equaled the ESS value of  $p$ , but in general it does not —  $p'$  here is the proportion of low  $d$ 's as measured by consumption, and may, in equilibrium, be greater or less than  $p$ , depending on the patterns of investment and consumption induced by other parameters. One thing is apparent, however, from an evaluation of our model; although significant investment is not precluded in our model by government 'theft', the point at which investment ends and all income is consumed depends critically both on  $r$  and the rate at which the ESS model is allowed to adjust  $p'$ . The change, moreover, is dramatic — even catastrophic — wherein for, say,  $r_0$  there is considerable investment, whereas for  $r_0 + e$ , where  $e$  is arbitrarily small, there is no investment whatsoever. Setting  $p = .5$ , Figure 11 graphs  $r$  against  $ar$ , the adjustment rate, such that high  $d$ 's invest for values of  $(r, ar)$  above the curve, whereas everyone consumes everything at their disposal for values below the curve.

#### 4. Conclusions

We cannot argue that the way we conceptualize and model endogenous discount rates is the uniquely best approach or even that it captures a majority of the essential features of corruption in a society. Certainly it is worthwhile to consider alternative growth models (see, for example, endnote 11), ways of making  $r$  endogenous, and alternative models of the process by which people influence each other's private discount rates. Admittedly, in this latter respect, an ESS model offers an especially tractable approach as compared to, say, one based on learning or even one in which people 'rationally' choose a rate on the basis of what they observe in their immediate environment. And although we can associate the

parameters of our ESS model with various classes of games, we have not yet linked those parameters to specific political-economic or social features of society. Nevertheless, our model is a departure from the approaches offered by the empirical literature and by those formal analyses that look at corruption as the product of some system of supply and demand relationships. By focusing on private discount rates and arguing that there is a logical connection between these rates and people's propensity to engage in corrupt acts, we are able to offer a number of hypotheses that have heretofore escaped notice. We see, for example, that the rate at which people shift between holding high versus low time discounts may be critical to the overall level of welfare (as measured by invested capital as well as by aggregate consumption; see Figures 9 and 10) — and, by implication, between welfare and corruption. Second, although we find that high levels of corruption in the form of a population that for the most part discounts time heavily might initially yield higher levels of consumption so as to give the impression that corruption 'greases the wheels' of an otherwise inefficient bureaucracy, Figure 5 suggests that this benefit is only temporary. Third, any exogenous factor that causes the equilibrium value of  $p$ , the proportion of the population that consumes rather than invests, to increase above zero will have, as Figure 3 shows, an initially disproportionate impact on social capital. Fourth, although it might seem that high rates of return on investments will induce savings, the effect in equilibrium is, in general, the opposite — an hypothesis that is not contradicted by patterns of domestic investment and inflated interest rates in the former Soviet Union. Finally, we see that although massive 'corruption' in the form of the outright theft of investments does not preclude investment, all invested capital can, in a catastrophic way, be converted to consumption if parameters cross a critical threshold. In this way systems with massive corruption are far more sensitive to fluctuations in parameters than are systems in which resources are transferred between high and low  $d$  types only in an evolutionary way. There, patterns of investment and consumption need not be especially high, but they do at least change continuously with parameter values. Again, then, we are reminded of the sudden conversion of private savings and surge of consumption in the former USSR when the government threatened (and indeed, via a variety of devices such as letting the ruble float, implemented) a massive redistribution of wealth.

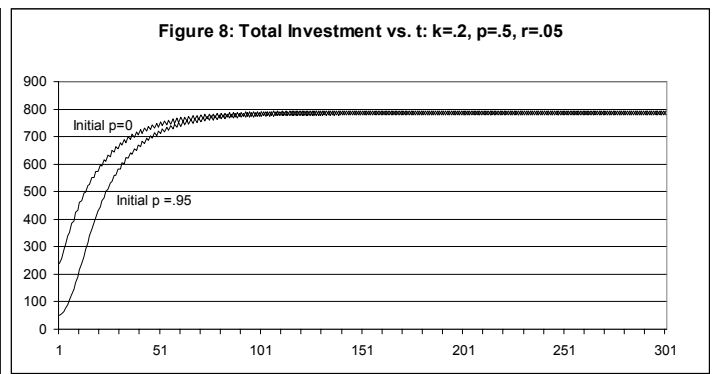
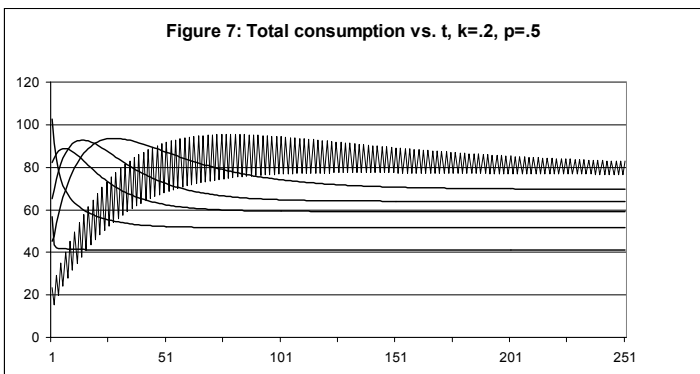
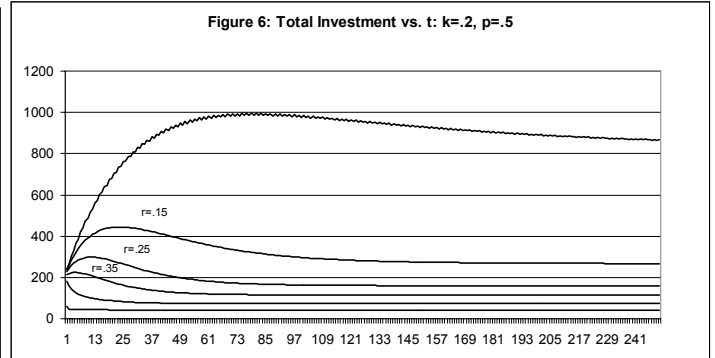
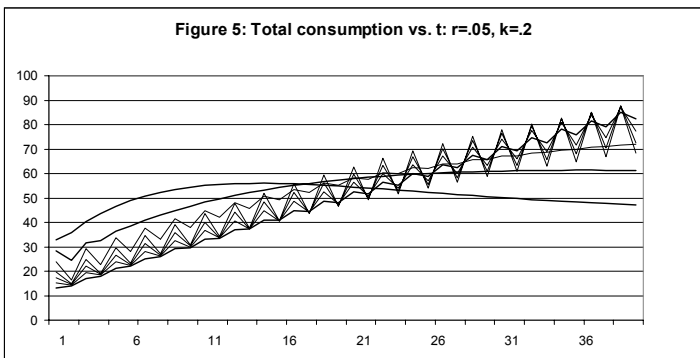
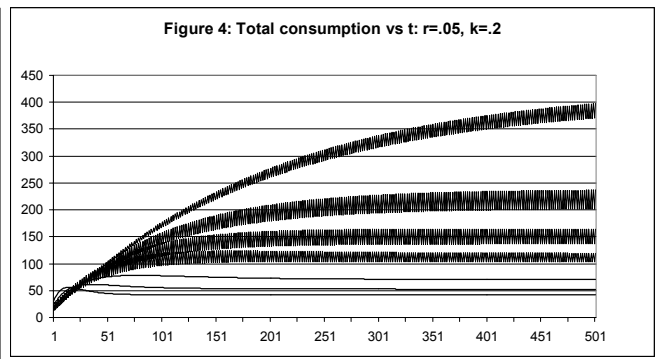
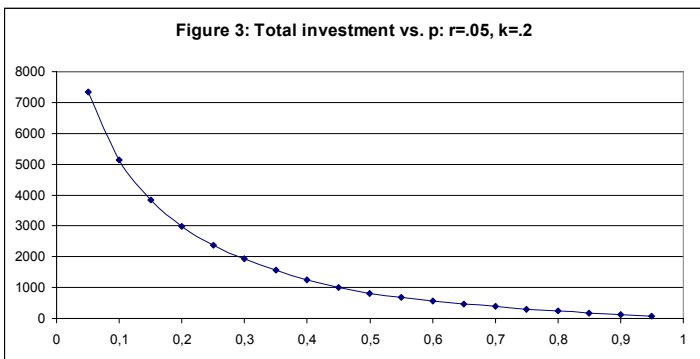
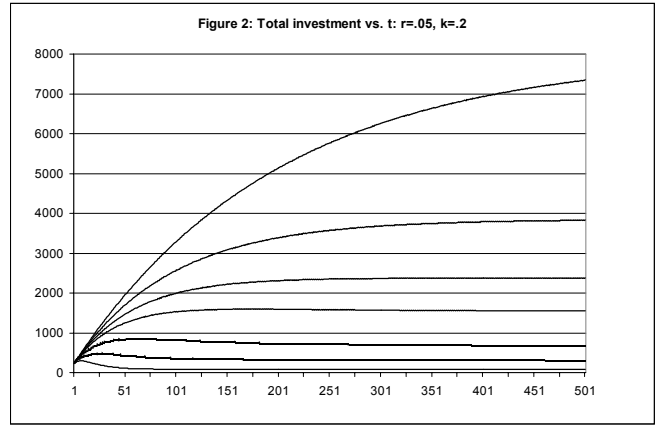
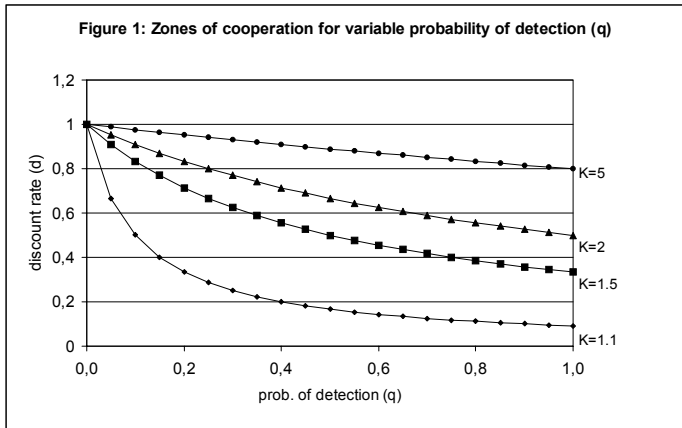
It should be noted that our analysis differs in a critical way from prior multi-period models that also suggest critical thresholds for various parameters. Those analyses typically offer a multi-period game among potentially corrupt bureaucrats and those who would buy favors from them (see for example Andvig and Moene, 1990), and as is commonly the case with repeated games, this formulation occasions critical thresholds for various parameters whereby unique equilibria exist for one range of values and multiple equilibria exist otherwise. Slight perturbations of parameter values (e.g., public salaries, perceived fraction of corrupt bureaucrats, detection probabilities), then, can abruptly change the character of equilibria, whereas wholly exogenous factors can dictate which equilibria prevails. In contrast, our analysis in effect takes the single play of such a simple exchange game, assumes that it models an evolutionary game, and uses the resulting ESS equilibrium of time discount rates as an input to a dynamic model of investment and growth. Thus, critical parameters arise here insofar as they dictate the ultimate equilibrium patterns of investment and consumption. However, the fact that we have not paid much attention to the embedded evolutionary game requires that we treat with care any conclusions we might offer that are at odds with prior analyses. For example, our earlier argument that the 'cure' for corruption may require a gradualist approach — policies that somehow encourage only moderate rates of change in private discount rates so as to allow for a build-up of savings among those who value the future — may be at odds with an analysis that foresees the need for policy that can somehow abruptly move a system in some discrete way from one stable equilibrium to another. Thus, citing empirical parallels to the hypotheses our model offers is a tenuous enterprise since that model, like any other, is limited by its assumptions and restrictive structure. Nevertheless, the often non-intuitive nature of our results suggests that examining the effect of endogenous time discount rates, along with the linkage of those rates to corruption, needs to be pursued so that we can better understand cooperation in all of its forms, good and bad.

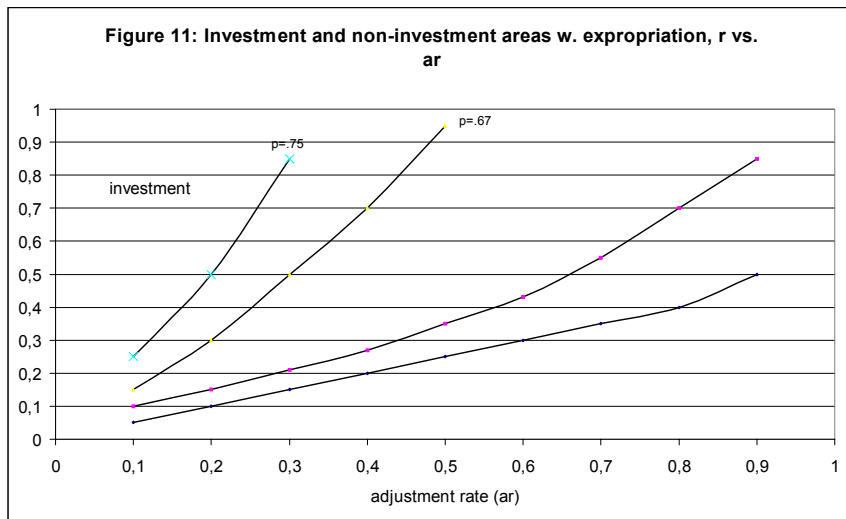
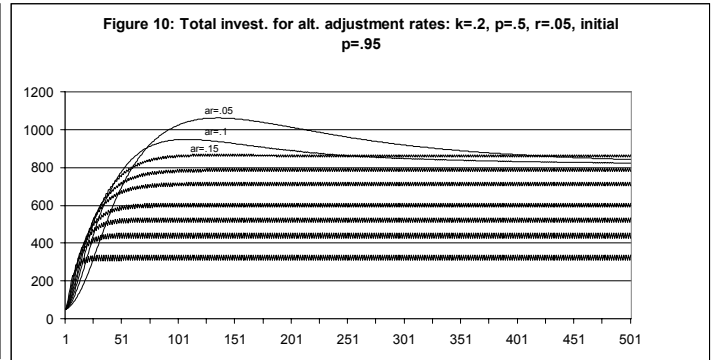
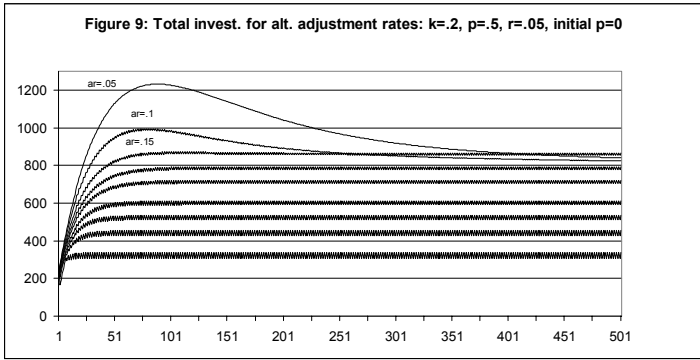
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Figures





## Endnotes

1. Kneen (2000), Waller, Verdier and Gardner (2000), Johnson, Kaufmann and Shleifer (1997), Johnson, Kaufmann, McMillian and Woodruff (2000), Friedman, Johnson, Kaufmann and Zoido-Lobaton (2000), and Shleifer and Vishny (1993), Hedlund (2001), Mo (2001), Wei (2000).
2. For explicit acknowledgment of this fact see, for instance, Mauro (1997).
3. Indeed, the preceding discussion ignores the issue of whether a grim trigger strategy is subgame perfect and, therefore, credible. However, our formulation seeks only to illustrate the dual role of  $q$  and  $r$ , and subgame perfect forms of tit-for-tat yield equivalent results.
4. Rose-Ackerman (1999: 31). A nearly equivalent argument is offered by Posner (2000: 5) in his discussion of signaling: «People who care about future payoffs not only resist the temptation to cheat in a relationship, they signal their ability to resist the temptation to cheat by conforming to styles of dress, speech, conduct, and discrimination. The resulting behavioral regularities, which I describe as 'social norms' can vastly enhance or diminish social welfare.»
5. See for example Greif, Milgrom and Weingast (1998), Andvig and Moene (1990), Bicchieri and Rovelli (1995), Mauro (1997), Sah (1987), Lui (1986), and Cadot (1987).
6. Some appreciation of the endogeneity of discount rates can be found in Rose-Ackerman's (1999: 34) discussion of the effects of corruption on firms that somehow become immersed in corrupt practices: «The claim of no impact on firm behavior is, however, too simple ... the corrupt nature of [a] deal may give the firm a short run orientation.»
7. For a discussion of the dynamics of corruption in the former Soviet Union following its dissolution see Kneen (2000).
8. It might seem strange to propose a model in which consumption increases with  $r$ , rather than decreases, so as to allow for greater investment. However, keep in mind that this is a steady state equilibrium result. Consider a more traditional model in which  $y_t = f(K_t)$  denotes the 'output' or return in period  $t$  if 'capital stock' is  $K_t$ , where the amount  $y_t$  must then be allocated between investment and consumption,  $y_t = I_t + C_t$ , and in which capital stock depreciates at the rate  $s$  so that a person's stock in the next period,  $t+1$ , equals the stock in the current period, minus depreciation, plus the output invested in period  $t$ . That is,  $K_{t+1} = I_t + (1-s)K_t$ . For a specific example, let  $y = f(K) = A(1 - e^{-bK})$ , in which case, if  $d$  is a person's time discount rate, then the optimal steady state equilibrium is characterized by the expressions  $y^* = f(K^*) = A(1 - (s+1/d-1)/Ab)$ ,  $I^* = sK^*$ , and,  $C^* = y^* - I^*$ . Thus, *ceteris paribus*, investment decreases and consumption increases as depreciation decreases. For the derivations using this numerical example, see Boylan, Ledyard, Lupia, McKelvey and Ordeshook (1991).
9. For an introductory discussion of evolutionary game theory and its relation to classical game theory see Avinash Dixit and Susan Skeath (1999), especially pages 320-52.
10. This follows from the fact that every ESS corresponds to a Nash Equilibrium in the corresponding matrix game (but not vice versa .... not every Nash equilibrium is ESS).
11. To see this, suppose  $(q, 1-q)$  is a mixed strategy equilibrium for column chooser. Then the expected payoff to row choose from the 'strategy' high  $d$ ,  $q - v(1-q)$ , must equal the expected payoff from the 'strategy' low  $d$ ,  $uq$ . Setting  $uq = q - v(1-q)$  and solving for  $q$  yields  $-v/(u-1-v)$ .
12. In the analysis that follows, we consider only the possibility of a polymorphic population since the ultimate consequence of one for which the ESS is all low  $d$ 's or all high  $d$ 's is obvious.
13. Not all low  $d$ 's are equal. Some have only their supplemental income to consume, while others have this income plus the returns on investment they earned when acting as high  $d$ 's. However, owing to the linearity of our model, we can sum these resources and analyze the situation as if there is a single consumer with a weight equal to the total of its consumption.
14. That is, if, say, 40% of lows are to be converted to highs in order to match the proportion of lows in consumption with the ESS value of  $p$ , we change the proportion of lows by .1 times 40% in that period.