Agent-Based Model of Corruption: Micro Approach

Replication of Ross Hammond's Corruption Model, 2009

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1 Transition from High to Low Corruption

Transition from high corrupt state to low corrupt state in a short period of time is relatively rare social phenomenon OECD (2005). Most studies treat corruption as a given socio-economic condition and focus on the effects of corruption, rather than on its causes and internal mechanisms Anderson and Gray (2006). Specifically in developmental context the idea often is that developed nations should help the less developed nations to make the transition from high levels of corruption to low levels of corruption. Opinions diverge though whether external actor's help can be effective Kaufmann (2005) and if so, what is the best strategy for the outside actors to influence the situation in less development countries Ampratwum (2008).

Hammond (2009) focuses on micro dynamics of corruption and the ability of the society to experience an endogenous transition from high corrupt state to low corrupt state. This paper builds on the working paper the Endogenous Transition Dynamics in Corruption: An Agent-Based Computer Model by Hammond (2009). Agent-based model that Hammond used to show this transition accounted for micro-level interactions between the population of citizens and bureaucrats that made quasi rational choice of choosing the corrupt or non-corrupt strategy. The agents in Hammond's model calculate probability of being caught for corrupt practices and probability of meeting a corrupt agent. The agents weigh their possible payoffs and make quasi rational decision whether to become corrupt or not corrupt. Agents are "moral" beings, having inherent moral property of "honesty." The assumption of the author of the model is that agents with high inherent "honesty" will pay high moral price for being corrupt and vice versa, the agents with low level of inherent "honesty" will pay low moral price for it. I describe Hammond's model, using ODD protocol for documenting agent-based models as shown in Railsback and Grimm (2011).

Examining the dynamic model of transition of corruption by Hammond, I found that the fluctuations from high corruption to low corruption were much more pronounced, than indicated in the original paper. See Figure 1 and Figure 2 for a typical pattern of changes in the population of 300 bureaucrats and 300 citizens in a base model that is de-
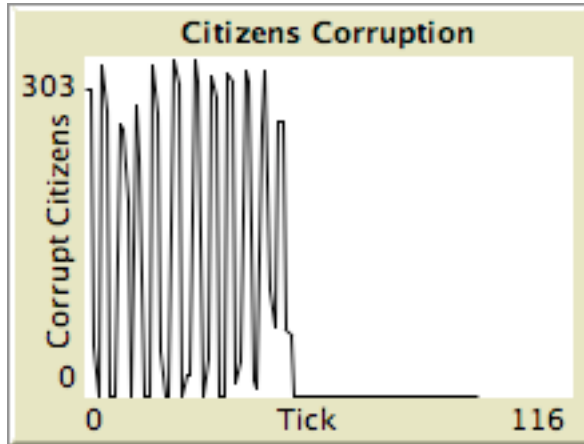
scribed in ODD protocol below in Table 4.
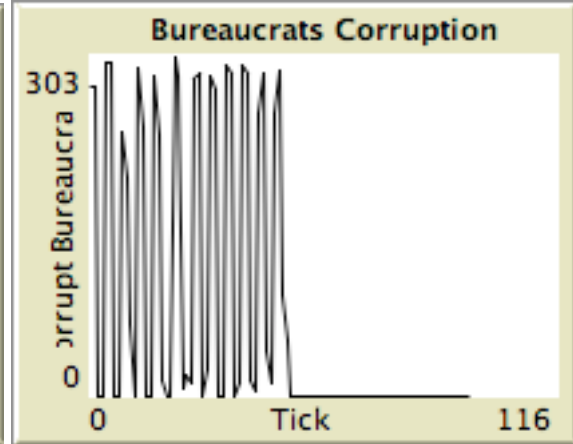

Figure 1: Citizens

Figure 2: Bureaucrats

The claim that heterogeneity of agents in terms of their inherent measurement of "honesty" was confirmed in the experiments. When honesty of all agents is set to an average of 0.5, instead of randomly assigned decimals between 0 and 1, including both extreme values, transition to non-corrupt state does not seem to happen. Another remarkable feature of the model is that whether it is assumed that the agent becomes non-corrupt after being "corrected" in jail or not, the transition to no corruption state still happens, although it is slower and in many instances transition to permanent corruption state happens. If the assumption about corrective quality of prison is removed, sometimes the model enters into permanent corrupt state as shown in Figures 3. Still in 2/3 of cases in my 35 runs, the system still transitioned to non-corrupt state, see Figure 4 and Table 2.

One of the principal arguments in Hammond (2009) is that agents should not be aware of the exact nature of the law enforcement efforts to combat corruption. As soon as agents become aware of all other agents' behavior, the model collapses into permanent corruption state. However, in my experiments, making all citizens and bureaucrats aware of other fellow agents' behavior still resulted in transition of the model to non-corruption state, see Table 5 and Table 6 at the end. Increasing the memory of the agent up to 500, all else being held as in the base model, also did not result in permanent corruption, the model still experienced the transition to non-corrupt state, as opposed to the results, shown in Hammond (2009).

The base model with the addition of two assumptions that,

- corrupt agents exclude themselves from the number of corrupt agents, when calculating probability of going to jail

- corrupt agents become non-corrupt after going to jail (but may become corrupt again after they leave the jail)

shows the results as in Table 1.

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Table 1: Base Model

Number of the Run	Time till Transition to Non-Corrupt State
1	110
2	32
3	39
4	217
5	54
6	64
7	483
8	165
9	160
10	15
11	170
12	49
13	231
14	18
15	115
16	71
17	6
18	56
19	101
20	189
21	6
22	7
23	79
24	187
25	39
26	490
27	58
28	163
29	365
30	10
31	64
32	126
33	207
34	72
35	120
Summary Statistics	
mean	123.94
variance	14657.23
st.dev.	121.07

Table 2: Base Model. No Prison Correction

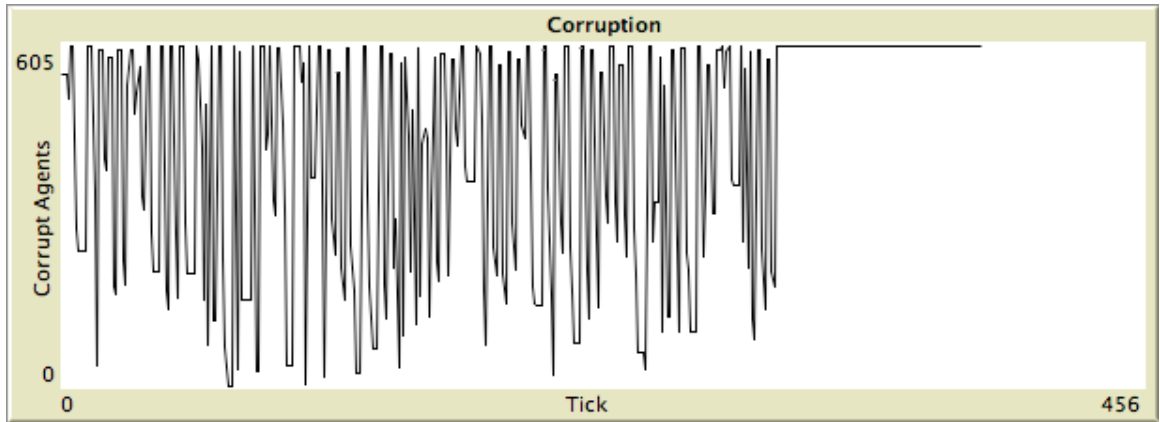| Number of the Run	Time in Ticks Until Transition to Equilibrium	State
1	504	Corrupt
2	1289	Corrupt
3	81	Corrupt
4	312	Corrupt
5	303	Non-Corrupt
6	155	Non-Corrupt
7	512	Non-Corrupt
8	478	Non-Corrupt
9	157	Corrupt
10	216	Corrupt
11	383	Non-Corrupt
12	59	Non-Corrupt
13	283	Non-Corrupt
14	57	Non-Corrupt
15	959	Non-Corrupt
16	88	Corrupt
17	19	Non-Corrupt
18	698	Non-Corrupt
19	198	Non-Corrupt
20	539	Non-Corrupt
21	25	Non-Corrupt
22	103	Corrupt
23	236	Corrupt
24	122	Non-Corrupt
25	350	Non-Corrupt
26	81	Non-Corrupt
27	19	Non-Corrupt
28	45	Non-Corrupt
29	107	Corrupt
30	672	Non-Corrupt
31	162	Non-Corrupt
32	534	Non-Corrupt
33	299	Non-Corrupt
34	1055	Corrupt
35	324	Non-Corrupt
Summary Statistics		
mean	326.4	
variance	95345.13	
st.dev.	308.78	
percent corrupt	31.43	
percent non-corrupt	68.57	

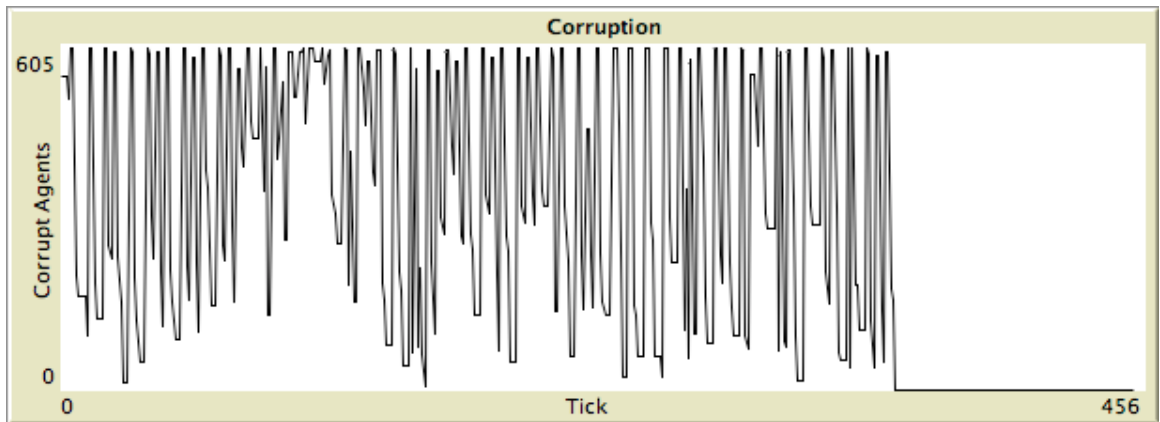Figure 3: Transition To Permanent Corruption. Jail Does Not Correct

Figure 4: Transition To Permanent Non-Corruption. Jail Does Not Correct

Once agents' ability to interact with each other in each round is not limited to one interaction, the model has difficulty to reach any equilibrium - either corruption state or non-corruption state.

2 ODD Protocol Application

3 Overview

3.1 PURPOSE

The model explores the conditions for an endogenous social transition from a high-corruption state to a low-corruption state. The majority of researchers focus on the effects on corruption, while this model specifically addresses the issue of dynamics of corruption. In particular, the model shows that "stable corrupt system" may be quite unstable and transition to lower level of corruption under certain conditions. The change happens endogenously, without any change in the system and its structure.

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Entities of the model include two types of individual agents, "citizens" and "bureaucrats", square grid, sized 33X33 that is not toroidal (does not wrap around), "social networks" that are represented by patches on which agents are stacked. Each group of agents of similar type that are on a patch comprise a "social network." This network is utilized by every agent in it to gather information and make decisions. "Jail" where some corrupt agents end up, according to the rules described below.

State variables include: strategy of the agent that can be either "corrupt" or "non-corrupt", inherent propensity for "honesty."

Each time period is made up of five steps: interaction of agents of different type, information gathering from the "social network", reporting of corrupt agents to the central authority, going to "jail" of corrupt agents, release of agents from "jail."[1]

Each time period consists of five stages:

- A "citizen" interacts with a random "bureaucrat"

- Both "citizen" and "bureaucrat" independently choose their expected payoff from corruption, based on a decision rule that is detailed below

- If either "citizen" or "bureaucrat" in each pair is corrupt and the other agent is not, the non-corrupt agent in the pair "reports" the corrupt agent to the central authority

- After an agent accumulates certain fixed number of "reports" of corruption, the agent goes to "jail." This means that the agent cannot receive payoffs and participate in the game for certain number of rounds

- Having served the "prison term", the agent is "released" with the strategy "non-corrupt"

4 Design Concepts

Unlike previous research that treated corruption as an exogenous factor, this model strives to show the dynamics of corruption in the society. The model attempts to show how and why transition from more corrupt state to less corrupt state might occur, assuming that majority of agents are corrupt and payoffs for corrupt interactions are higher, than payoffs for non-corrupt interactions. The agents are modeled with limited, bounded rationality whose decisions are based not on universal knowledge of the rules, but rather on the local

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[1]"jail" procedure adapted from Uri Wilensky's 2004 model Rebellion

knowledge of their local network.

4.2 EMERGENCE

The primary result of the simulation is that after "arrests" of "corrupt" agents mount, the released agents change their strategy to "non-corrupt" that spreads the wave of honesty. There are increasingly more mismatches between "corrupt" and "non-corrupt" agents, which results in ever greater numbers of "corrupt" agents to go to "jail" and contribute to spreading "honesty." As a result of these trends an endogenous transition from corruption to honesty happens in the system. The key assumptions are that an agent after serving the "prison term" adopts "non-corrupt" strategy, that corrupt agents are accurately reported to the authorities each time and that the central authorities act strictly according to the law.

4.3 ADAPTATION

Agents decide whether to engage in corrupt activities or not, based on the decision rule that includes probability of encountering a corrupt agent, probability of chances of being caught for a corrupt dealing, the fixed payoff for corrupt interaction and the fixed payoff from non-corrupt interaction.

So, an agent of type i contemplates receiving the following payoff as the result of corrupt interaction:

$$(1 - B)[Ax_i + (1 - A)y] + B[y - ky]$$

A is the likelihood of encountering a corrupt agent. $A = n/N$, where n is the number of corrupt agents who the agent met in N previous interactions. B is the perceived chances of being caught for a corrupt action in this round. $B = m/M$, where m stands for the number of the agent's friends (agents of its own type that are on the same patch) in jail. M is the number of the agent's friends who were corrupt during the last round. x is the payoff of corrupt agent and y is the payoff of the non-corrupt agent. Only if both interacting agents are corrupt the maximum payoff y can be achieved, as detailed in Table 1.

Table 3: 2x2 Payoff Matrix

	Corrupt	Non-Corrupt
Corrupt	x	y
Non-corrupt	y	y

The model is further complicated by every agent's inherent propensity for honesty

that stands for a moral quality that adversely affects the payoff of the honest agent that indulges in corrupt activities. For an i of 1 that represents perfect honesty, this moral damage would be very high, while for an i of 0 that represents perfect corruption, the moral price would be zero. So, every agent perceives its own x differently, even though the x - payoff of corrupt agent - is of a fixed value in the game. Perfectly honest agent gains zero from corrupt interaction, while only perfectly corrupt agent gains the full amount of x.

$x_i = (1 - i)x$

4.4 OBJECTIVES

Highest payoff is the primary objective of the agent. The constraints are probability of being caught for corruption, probability of meeting a non-corrupt agents, inherent honesty that reduces payoff

4.5 LEARNING

Agents change their strategy from "corrupt" to "non-corrupt", following the "imprisonment" and subsequent "release." Agents learn from their "social network" to adjust their strategy.

4.6 PREDICTION

Agents have limited memory of how many corrupt agents they met in fixed number of last rounds. The observer has the memory of how many times an agent was "turned in".

4.7 SENSING

The agent can only see the agents of its own type that are situated on the same patch as the agent itself. This "social network" of an agent is used to gather dynamically the information about number of "friends" in "jail" and number of "corrupt" agents. The agent uses this information to estimate its highest possible payoff.

4.8 INTERACTION

Only pairs of different types of agents, "citizens" and "bureaucrats" can interact with each other. The interaction was modeled on the interaction of corrupt officials and citizens. Both are assumed to have equal propensity for corrupt practices.

4.9 STOCHASTICITY

Agents are assigned randomly (uniform) distribution of inherent propensity for honesty, decimal values from 0 to 1. This setup is designed to show inherent moral qualities of individuals that are relatively stable. Each round "citizens" interact with "bureaucrats" on

random basis. This process shows the real world interactions of citizens with variety of government offices.

4.10 Collectives

The collective are fixed. There are two types of agents, "citizens" and "bureaucrats." Each of the agent types is further subdivided into smaller groups. Both divisions are fixed and do not change for the duration of game, except for corrupt individuals that were reported to the central authority more than certain number of times. These corrupt individuals are "jailed", but they are "released" into the same group where they were before.

4.11 Observation

The transition from corrupt behavior to non-corrupt behavior is the primary observable that we should see. So, the output that is needed to see is whether the number of corrupt agents decrease over time.

5 Details

5.1 Initialization

Create empty torus of size LatticeSize x LatticeSize (default 33 x 33) [Von Neumann geometry]

Table 4: Base Model

x base payoff to corruption	20
y payoff to honesty	1
i inherent propensity for honesty	uniformly distributed decimals $[0, 1]$
N size of memory	5 rounds
M size of social network	10 agents
k length of jail term	2 rounds

5.2 Input Data

The environment is assumed to be constant, so there is no input data

5.3 Submodels

- "interact". A "citizen" interacts with a random "bureaucrat", both agents should not be in "jail". If the pair of agents have different strategies on corruption, i.e. one is corrupt and the other one is not, the corrupt agent is reported to the central authority. If two corrupt agents interact they both receive highest payoff x, otherwise each agent receives payoff y.

- "decide". Both the "citizen" and the "bureaucrat" that are out of "jail" independently calculate their expected payoff from corruption, based on the decision rule. If the output of $(1-B)[Ax_i+(1-A)y]+B[y-ky]$ is greater than y, each agent rationally makes the decision to become "corrupt" (set its color to red)

- "enforce". After an agent accumulates certain fixed number of "reports" of corruption, the agent is sent to "jail. The affected agent sets its color to white, its active status to false, its jail term to specified k, receives a payoff in the amount of y and resets its counter of reports to 0. Being in "jail" means that the agent cannot receive payoffs and participate in the game for certain number of rounds, specified in k.

- "release". Having served the "prison term", the agent is "released".

- reporter "agent-payoff" reports the weighted payoff of an agent $x_i = (1-i)x$

- reporter "encounter-corrupt-agent" calculates the probability of the agent of encountering a corrupt agent, given the count of corrupt agents it encountered in N previous rounds

- reporter "perceive-chances-of-jail" reports calculates "subjective" probability of being caught for corrupt dealings that is given as number of corrupt agents in jail form the patch of the agent divided by the total number of corrupt agents from the same patch

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Railsback, Steven F and Volker Grimm. 2011. *Agent-based and individual-based modeling: a practical introduction.* Princeton University Press.

Table 5: Base Model. Memory 500

Number of the Run	Time Till Transition to Non-Corrupt State
1	223
2	12
3	328
4	27
5	42
6	117
7	235
8	6
9	46
10	40
11	83
12	475
13	140
14	102
15	271
16	107
17	3
18	10
19	84
20	111
21	194
22	40
23	411
24	157
25	44
26	27
27	39
28	28
29	24
30	223
31	54
32	240
33	87
34	120
35	32
Summary Statistics	
mean	119.49
variance	13865.02
st.dev.	117.75

Table 6: Base Model. No Prison Correction. Memory 500

Number of the Run	Time Till Transition to Equilibrium	State
1	657	Non-Corrupt
2	12	Corrupt
3	1951	Non-Corrupt
4	345	Non-Corrupt
5	198	Non-Corrupt
6	465	Non-Corrupt
7	200	Non-Corrupt
8	1064	Non-Corrupt
9	494	Non-Corrupt
10	1184	Non-Corrupt
11	29	Non-Corrupt
12	115	Corrupt
13	4	Non-Corrupt
14	194	Corrupt
15	796	Non-Corrupt
16	22	Non-Corrupt
17	529	Non-Corrupt
18	474	Non-Corrupt
19	648	Corrupt
20	317	Corrupt
21	627	Non-Corrupt
22	3546	Non-Corrupt
23	159	Corrupt
24	444	Corrupt
25	639	Non-Corrupt
26	241	Non-Corrupt
27	1002	Non-Corrupt
28	559	Corrupt
29	33	Corrupt
30	416	Non-Corrupt
31	2295	Corrupt
32	140	Corrupt
33	498	Corrupt
34	167	Corrupt
35	171	Non-Corrupt
Summary Statistics		
mean	589.57	
variance	521000.31	
st.dev.	721.80	