The Effects Of Neighborhood On Tax Compliance Rates: Evidence From An Agent Based Model

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THE EFFECTS OF NEIGHBORHOOD ON TAX COMPLIANCE RATES: EVIDENCE FROM AN AGENT-BASED MODEL

M. Oğuz ARSLAN* Özgür İCAN**

Abstract

This paper investigates the effects of neighborhood on tax compliance behavior of taxpayers based on an agent-based tax compliance model. To this aim, it is attempted to find out different tax compliance patterns under different "penalty rate - audit rate" combinations and for von Neumann neighborhood, Moore neighborhood, and no neighborhood schemes. The findings throw into sharp relief that both von Neumann and Moore neighborhoods are reducing compliance behavior of taxpayers considerably. The results of scenario runs put the case clearly.

Key Words: Tax Compliance, Agent-Based Modeling, NetLogo

Introduction

Agent-based modeling has proven to be an alternative technique in modeling tax compliance behavior of taxpayers. It has been becoming more popular among the public finance researchers as a dependable tool for simulating real life behavior of taxpayers especially since the beginning of 2000s. A quick literature overview about the subject can yield many papers devoted to the subject. Among them, Mittone and Patelli (2000) that examines the effects of initial mix of taxpayers about tax evasion in the situations of no audits and uniform auditing; Davis *et al.* (2003) that investigates the use of enforcement measures by tax authority; Antunes *et al*. (2006) that discusses the effects of ideas and facts on individuals; Korobow *et al.* (2007) that explores the effects of weighting neighbors payoffs on taxpayers agents; Hokamp and Pickhardt (2010) that analyzes evolution of income tax evasion; and Bloomquist (2011) that analyzes tax compliance behavior of taxpayers from the perspective of evolutionary dynamics are of particular importance.

Some of the well-known agent-based models are based on the idea that taxpayers exhibit some distinct characteristic behavior and thus can be represented as pre-defined archetypes. Those archetypes are limited number of taxpayer profiles, which differ from each other according to their attitude towards tax reporting. For example, in Mittone and Patelli (2000) taxpayers were classified into three groups: honests, imitatives, and perfect free riders to name all taxpayers. In Davis *et al.* (2003),

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only two groups of taxpayers were defined: honests, and evaders. In Bloomquist (2011) which is also our reference paper, taxpayers were classified into four groups: *defiants, honests, strategics* and *randoms* to name them all. In that study, a fixed amount of agents were initiated in a two dimensional world, honoring all of these archetypes with varying personal attributes such as income. As one might guess, parameters such as audit rate and penalty rate were global and generally applicable for all agents.

The Agent-Based Simulation Model

We construct an agent-based simulation model based on the Small Business Tax Compliance Simulator (SBTCS) described in Bloomquist (2011), an agent-based model that simulates US small business owners' tax reporting compliance. The SBTCS model is composed of four taxpayer archetypes based on the idiom that business owners exhibit heterogeneous tax morale and thus compliance behavior. These archetypes are characterized as defiant agents (i.e. malevolent agents with fully incompliant tax reporting behavior), honest agents (i.e. benevolent agents with fully compliant tax reporting behavior), strategic agents and random agents. Strategic agents are representing taxpayers who are regulating their tax compliance level according to their prior audit experience. These agents are using a simple reinforcement "learning" by slightly increasing their level of compliance if they are selected for an audit in previous time period and vice versa. Random agents behave in a random manner assuming that their behavior is a consequence of misunderstanding or misinforming of tax regulations.

Our model is basically a slightly modified version of SBTCS, having run with real parameters reflecting real Turkish tax reporting data and implemented using NetLogo 4.1.3 (Wilensky 1999) platform. Model world consists of a totaling 10,000 agents initially assigned to a random archetype spread across 100 x 100 two-dimensional grid.

The model strives to simulate the evolution of mean tax compliance of the overall population while respecting their individual attitude toward tax reporting. In each time period, agents supposed to earn an amount of income according to a "uniform" or "lognormal" income distribution selected by the user. Moreover, agents set their compliance level according to the attributes of the belonged archetype class. After that, some of the agents (exact number is determined by auditing rate and related parameters) are selected for an audit using one of the three types of selection methodologies. These methods include "random selection", "DIF-like select" (a method which tries to emulate US Internal Revenue Service's real life audit selection procedure) and "half-half method" which is a hybrid of these two. If there is an underreporting detected then the agent is forced to pay both the tax and an amount of punishment according to a predefined fine rate.

Unlike SBTCS, our model assumes that whatever the archetype, all of the agents shift to full compliance, if (perceived or actual) audit rate is over the threshold value. This threshold value comes from the classical model given by Allingham and

Sandmo (1972) based on utility theory. According to the model, a taxpayer's expected utility from reporting *x* dollars of income is given by:

$$E(x)=(1-p)(y-tx)^{\alpha}+p[y-ty-\varphi(ty-tx)]^{\alpha} \quad (1)$$

where *p* stands for probability of detection, i.e. audit rate, *y* is annual taxable income, φ is the penalty per dollar that is not reported and, α is the coefficient of relative risk aversion which is 1 for risk-neutral taxpayer. Differentiating the equation (1), a risk-neutral taxpayer should report zero income when $p<1/(1+\varphi)$ according to the classical model. In our model, instead of reporting 0 income, agents' behavior corresponds with their archetypes' up to the threshold value. After that value, every agent behaves fully compliant no matter belongs to which archetype.

The model implements perceived auditing and neighborhood effect as described in Bloomquist (2011, 37-41).

If enabled, perceived auditing rate is calculated according to the formula given by Bloomquist (2011, 38):

$$\hat{p}=1-\frac{(1-p)^{\gamma}}{\left(p^{\gamma}+(1-p)^{\gamma}\right)^{\frac{1}{\gamma}}} \quad (2)$$

where using *γ* as a weighting parameter for actual audit rate.

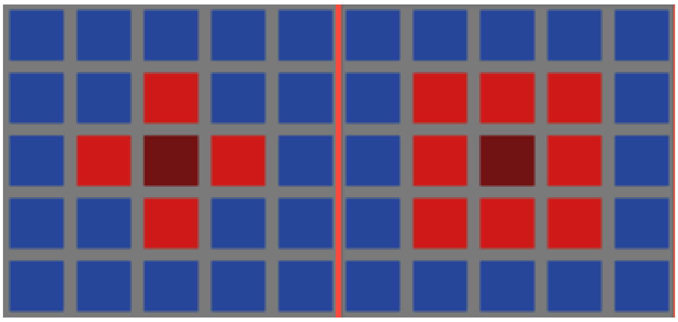
We use two neighborhood types, von Neumann and Moore neighborhoods, in our model (as mentioned in detail in Part 3 below). Von Neumann neighborhood effect is implemented as described in SBTCS, causing freshly created agents who are replacing bankrupted or leaving agents, to be turned into a defiant or honest taxpayer, if there is two or more agents of that archetypes within its neighborhood and total number of that archetypes in whole population is greater than the other ones total number in population. If these rules do not hold, then the freshly created agents are assigned to a random archetype class.

Moore neighborhood effect is implemented causing freshly created agents who are replacing bankrupted or leaving agents, to be turned into a defiant or honest taxpayer, if there is four or more agents of that archetypes within its neighborhood and total number of that archetypes in whole population is greater than the other ones total number in population. If these conditions are not met, then the freshly created agents are assigned to a random archetype class.

The Effects of von Neumann and Moore Neighborhoods in the Context of Audit and Penalty Rates

Neighborhood effect is an interesting concept that deserves special attention to arrive at a conclusion in search of tax compliance behavior of taxpayers. In that sense, neighborhood effect can be defined as a variable that explains the tendency of a taxpayer to comply with tax codes -and of course, to decide paying or not paying her/his taxes- in a certain direction based upon the relational effects of the taxpayers who are living in the neighborhood. Although there are various types of neighborhood in related areas of mathematics, we only used von Neumann and Moore neighborhoods as the two most common neighborhood types in two-dimensional cellular automaton models for testing and comparing neighborhood effects in our model.

In cellular automaton models, a von Neumann neighborhood is defined as a neighborhood that comprises four cells orthogonally surrounding a given cell on a two-dimensional square lattice whereas a Moore neighborhood is defined as a neighborhood that comprises eight cells surrounding a given cell on a two-dimensional square lattice, as shown in Fig. 1 (a) and (b) respectively.



(a) (b)

Figure 1: (a) A von Neumann neighborhood, (b) A Moore neighborhood.

In tax compliance literature, there have been a few studies that deal with neighborhood effects in the context of agent-based modeling. These studies are Bloomquist (2006, 2008), Korobow *et al.* (2007), and Andrei *et al.* (2011). Among them, Bloomquist (2006, 2008) represent that the larger the social network of taxpayer agents, the greater the tax compliance rate of the society. Korobow *et al.* (2007) asserts that a society behave compliant when taxpayers focus on their own individual decisions and the taxpayers remains largely non-compliant in the presence of neighborhood effects.

Andrei *et al.* (2011) analyze tax compliance behaviors of agents by using six different network structures (as von Neumann and Moore neighborhoods, one-dimensional closed ring world, Erdos-Renyi network, Small Worlds network, power law distributed network). The findings demonstrate that taxpayers are more likely to have a higher voluntary mean tax rate, i.e. higher mean compliance rate, in networks with higher levels of centrality across taxpayer agents. Andrei *et al.* (2011) also represents that von Neumann neighborhood brings forth the lowest tax compliance rate although Erdos-Renyi network and Moore neighborhood bring forth the two highest tax compliance rates.

In our study, we have strived to find different tax compliance patterns under different "penalty rate - audit rate" combinations and for von Neumann neighborhood, Moore neighborhood, and no neighborhood schemes. In order to accomplish this task we have determined four key audit rates (among them, 0.023 is real audit rate of Turkey that is derived from various annual reports of The Presidency of Revenue Administration, and a high rate of 0.20 is for controlling other rates) and three penalty rates as given in Table 1.

Table 1: Scenarios According to *phi* - *p* Combinations

		phi (i)		
		Penalty: 50 %	Penalty: 100 %	Penalty: 150 %
p (j)	Audit: 0.023	S_{11}	S_{21}	S_{31}
	Audit: 0.046	S_{12}	S_{22}	S_{32}
	Audit: 0.069	S_{13}	S_{23}	S_{33}
	Audit: 0.20	S_{14}	S_{24}	S_{34}

We have run our system for 12 scenarios each one for twice, resulting in 24 runs. The compliance rates at the end of these scenario runs for three different neighborhood schemes are given in Table 2. Also, the three-dimensional graphs of the first and the second simulation runs for three neighborhood schemes (by order of Moore neighborhood, von Neumann neighborhood, and no neighborhood) are given Appendix 1 and Appendix 2 respectively. The complete trends of compliance rates for 12 scenarios both in the first run and in the second run are given graphically in Appendix 3 and Appendix 4 respectively.

Table 2: Compliance Rates at the End of Scenario Runs

	First Runs			Second Runs		
S_i	*Moore*	*von Neumann*	*no neigh.*	*Moore*	*von Neumann*	*no neigh.*
S_1	0.189	0.182	0.398	0.154	0.211	0.394
S_1	0.120	0.136	0.433	0.136	0.156	0.427
S_1	0.165	0.150	0.470	0.150	0.137	0.461
S_1	0.094	0.125	0.530	0.090	0.132	0.530
S_2	0.186	0.197	0.398	0.177	0.213	0.395
S_2	0.124	0.143	0.425	0.140	0.156	0.426
S_2	0.131	0.170	0.462	0.127	0.163	0.466
S_2	0.150	0.133	0.533	0.157	0.172	0.528
S_3	0.166	0.243	0.397	0.159	0.238	0.401
S_3	0.150	0.169	0.428	0.143	0.156	0.425
S_3	0.149	0.157	0.465	0.151	0.148	0.459
S_3	0.170	0.185	0.530	0.154	0.145	0.530

With these runs, we have arrived at some interesting results on tax compliance behavior of taxpayers. Firstly, it is very clear that, without a neighborhood, tax compliance rates of taxpayers are high enough. As shown on Table 1 above, tax compliance rates range from a minimum of 0.394 up to a maximum of 0.533 in the first and second runs. These results mean that both von Neumann and Moore neighborhoods are reducing compliance behavior of taxpayers considerably.

When we take penalty rate constant, it is seen that audit rate affects compliance rate inversely proportional. However, without a neighborhood effect this situation occurs in direct contradiction. In other words, when penalty rate is taken constant mean compliance rate responds to increases in audit rate as expected. It means that neighborhood effect has negative influence on tax compliance behavior of taxpayers. That is to say, density of audit in low penalty rate is not important but increases in audit rate are effective together with high penalty rate. The results of either runs put the case clearly.

Theoretically, it is generally accepted that a desirable tax compliance rate can be reached through fine tunings in some variables such as audit rate, and penalty rate. However, neighborhood effect may invalidate this situation. Moreover, this situation may change according to type of neighborhood. In this paper, for example, Moore neighborhood yield worse compliance rate than von Neumann neighborhood. This is because Moore neighborhood is a surrounding that more agents affect one another. This result is expected result for this study.

Figure 2: Screen Capture of a Scenario Interface with von Neumann Neighborhood

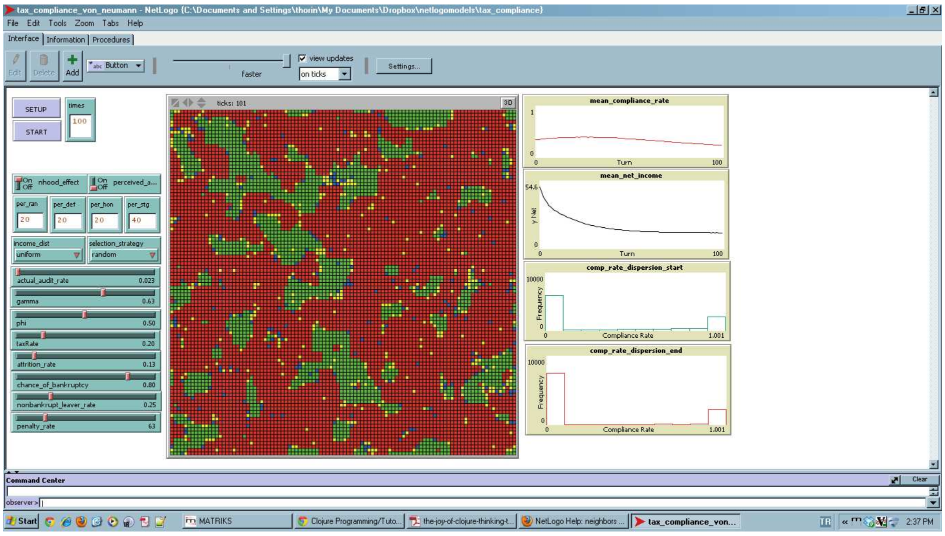
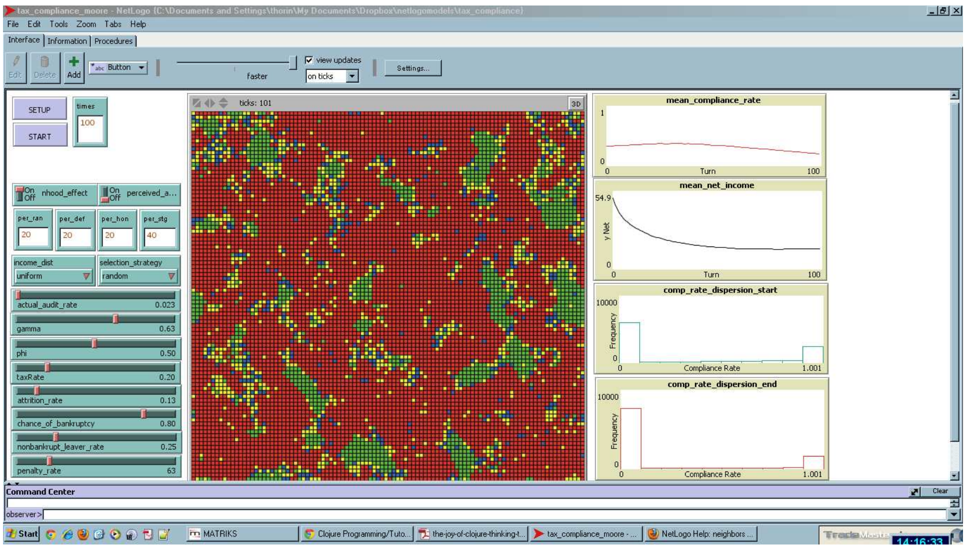


Figure 3: Screen Capture of a Scenario Interface with Moore Neighborhood



Conclusion

In this study, we have arrived at some noteworthy results on tax compliance behavior of taxpayers using agent-based strategy simulation. At first, it is become evident that without a neighborhood, tax compliance rates of taxpayers are high enough. In other words, both von Neumann and Moore neighborhoods are reducing compliance behavior of taxpayers considerably. Namely, density of audit in low penalty rate is not important but increases in audit rate are effective together with high penalty rate. The results of two runs put the case clearly.

Additionally, it is easily seen that neighborhood effect may invalidate policies of tax administration, which based on the idea that the expected tax compliance rate can be achieved through adjustments in some variables such as audit rate, and penalty rate. Besides, it is understood that types of neighborhood may affect the degree of invalidation of tax policies. For example, the two runs of the scenarios reveal that Moore neighborhood result in worse compliance rate than von Neumann neighborhood due to comprising more agents interacting with each other.

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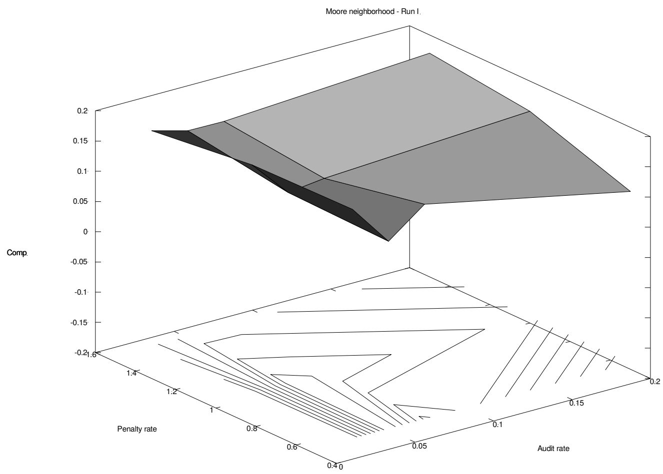
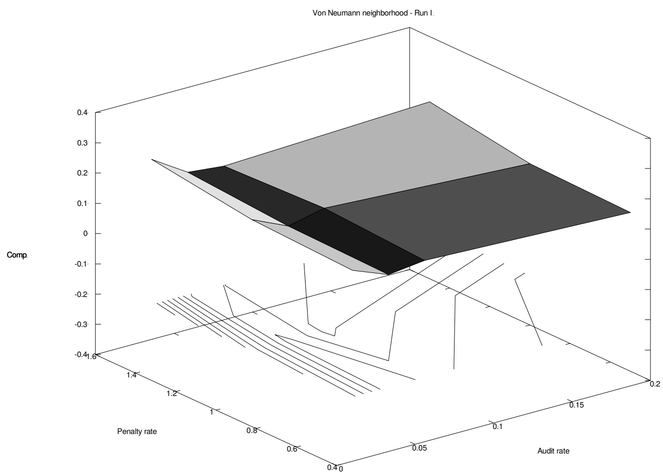
Appendix 1


Moore neighborhood - Run I.
Comp.
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
1.6
1.4
1.2
1
0.8
0.6
0.4
Penalty rate
0
0.05
0.1
0.15
0.2
Audit rate


Von Neumann neighborhood - Run I.
Comp.
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
1.6
1.4
1.2
1
0.8
0.6
0.4
Penalty rate
0
0.05
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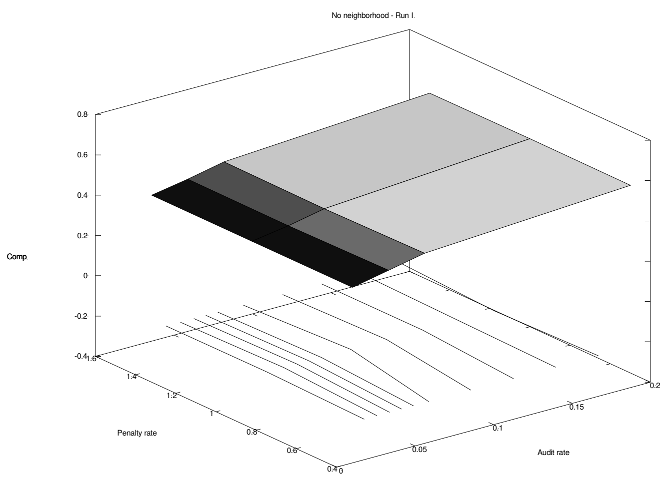
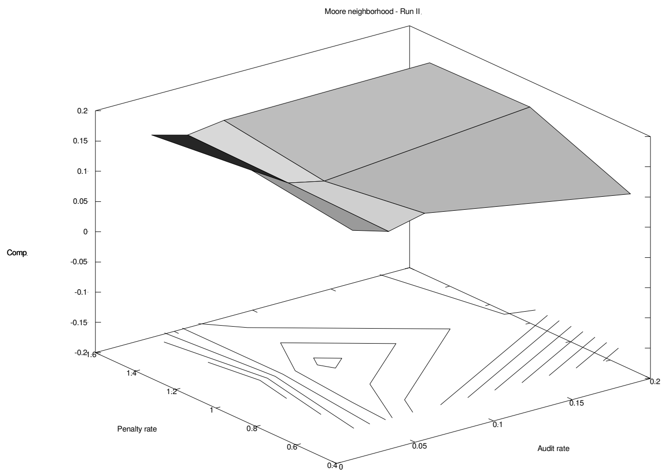
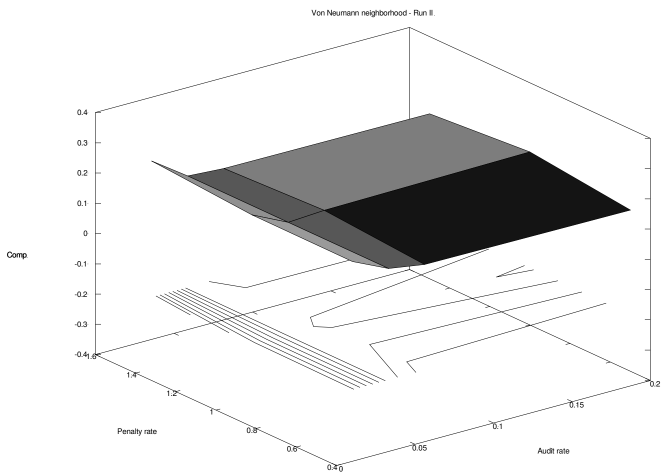
0.2
Audit rate


No neighborhood - Run I.
Comp.
0.8
0.6
0.4
0.2
0
-0.2
-0.4
1.6
1.4
1.2
1
0.8
0.6
0.4
Penalty rate
0
0.05
0.1
0.15
0.2
Audit rate

Appendix 2



Moore neighborhood - Run II
Comp.
Penalty rate
Audit rate
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
1.6
1.4
1.2
1
0.8
0.6
0.4
0
0.05
0.1
0.15
0.2



Von Neumann neighborhood - Run II
Comp.
Penalty rate
Audit rate
0.4
0.3
0.2
0.1
0
-0.1
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-0.3
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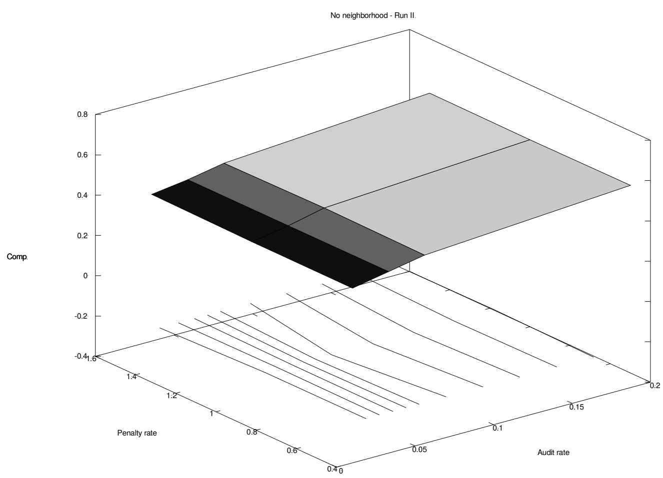

No neighborhood - Run II
Comp.
Penalty rate
Audit rate
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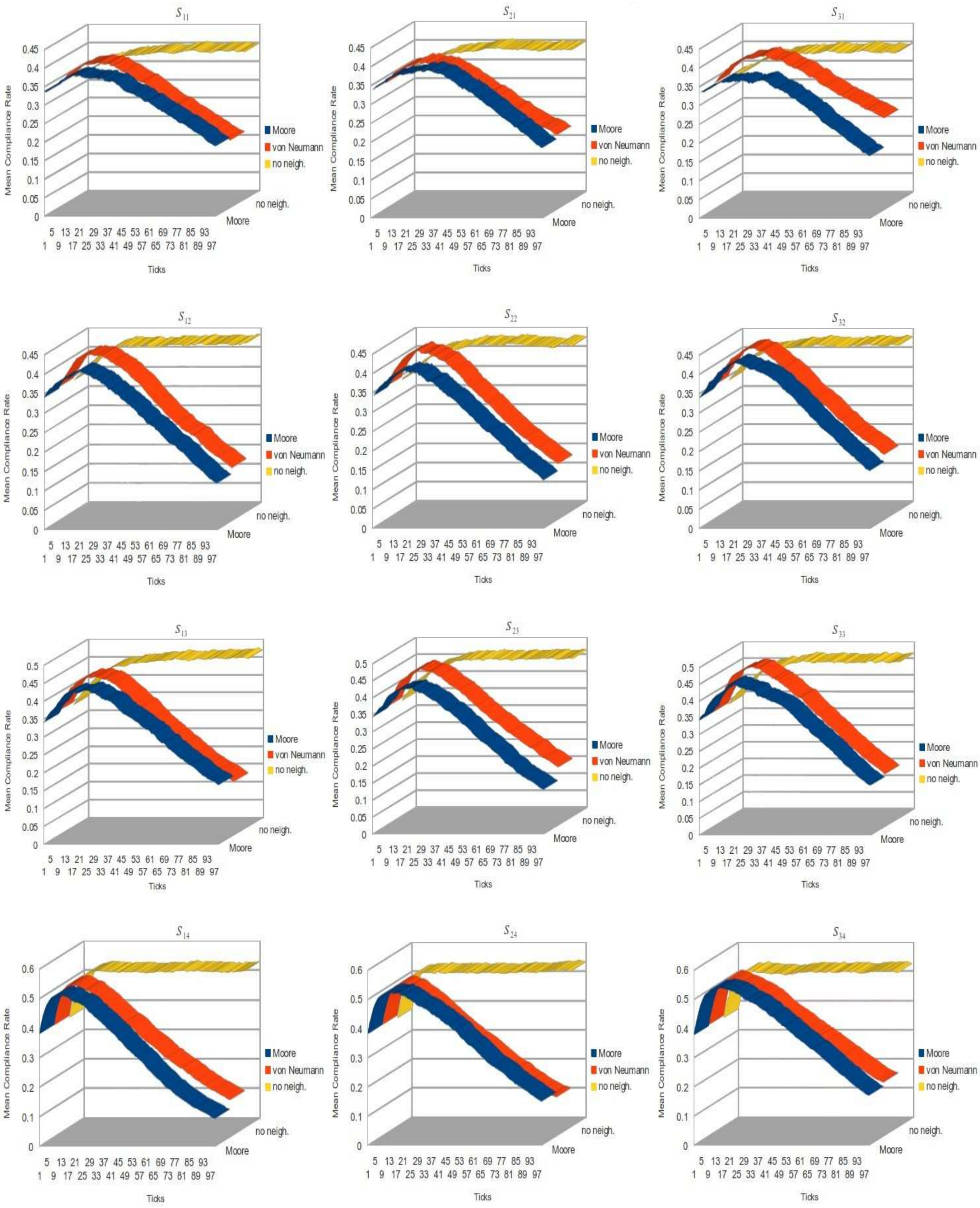
Appendix 3



S_{11}
S_{21}
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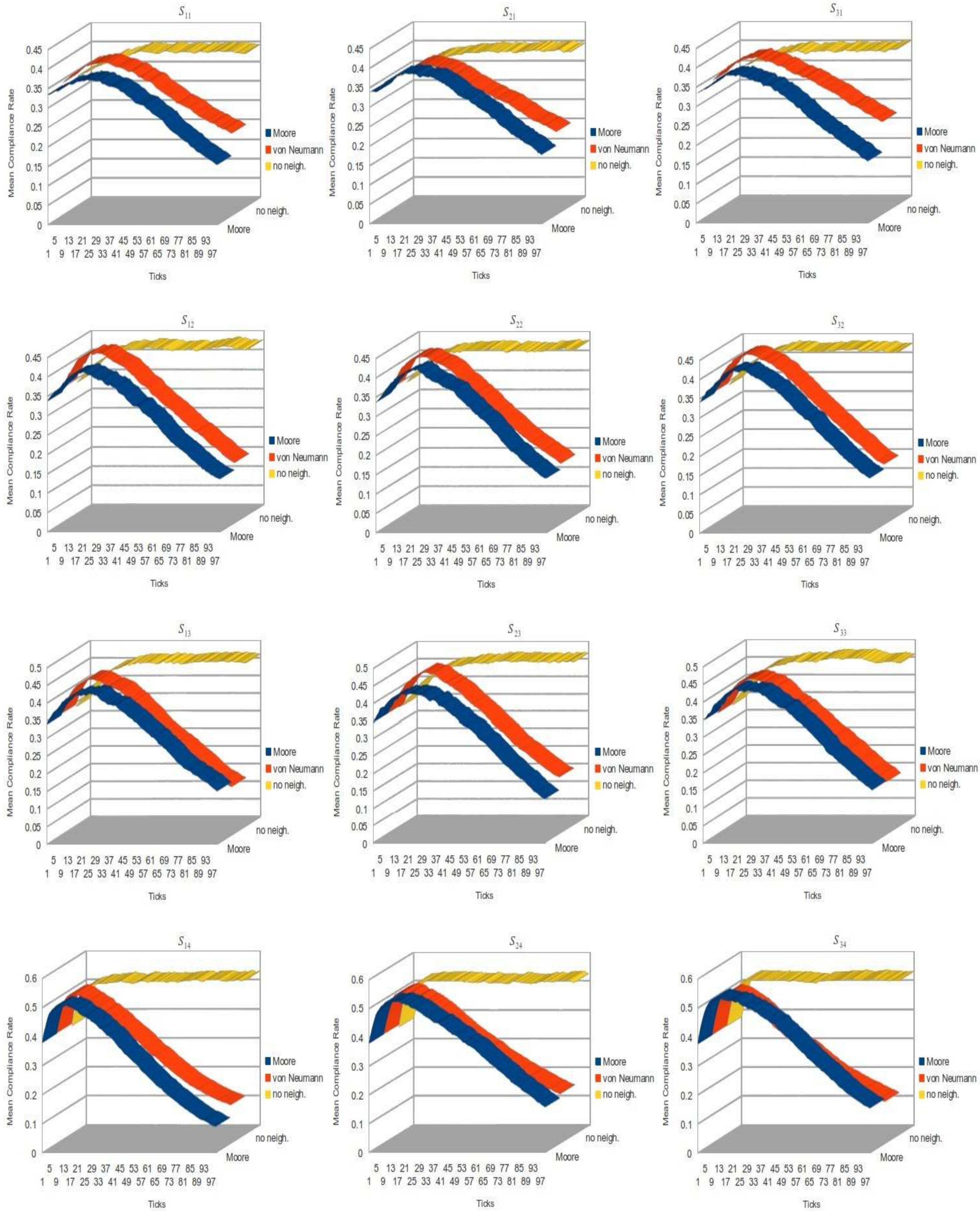
Mean Compliance Rate
Ticks
Moore
von Neumann
no neigh.

Appendix 1


S11
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S34
Mean Compliance Rate
Ticks
5 13 21 29 37 45 53 61 69 77 85 93
1 9 17 25 33 41 49 57 65 73 81 89 97
Moore
von Neumann
no neigh.
Moore
no neigh.