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An Agent-Based Analysis of Tax Compliance for Turkey

Türkiye'de Vergi Uyumunun Birey-Tabanlı Bir Analizi

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Abstract

An agent-based tax compliance model for Turkey is developed in this paper. In this model, four kinds of agent archetypes as honest, strategic, defiant, and random are employed. The model is used for simulating evolus tionary changes in tax compliance behavior of a population of 10,000 taxpayer agents. The implementation of the model via four simulation scenarios points out that an agent-based evolutionary strategy simulation for Turkish case is valid. Also, the neighbourhood effect is not found to be a determining factor for this case.

Keywords: *Tax Compliance, Tax Evasion, Agent-Based Modeling, NetLogo*

Öz

Bu çalışmada Türkiye için bir birey-tabanlı vergi uyumu modeli geliştirilmiştir. Bu modelde dürüst, stratejik, uyumsuz ve rassal olmak üzere dört çeşit birey arketipi kullanılmıştır. Model 10.000 vergi mükellefi bireyden oluşan bir topluluğun vergi uyum davranışındaki evrimsel değişiklikleri benzetim için kullanılmıştır. Modelin dört benzetim senaryosu ile çalıştırılması bir birey-tabanlı evrimsel strateji benzetiminin Türkiye örneğinde geçerli olduğunu göstermektedir. Ayrıca, bu örnekte komşuluk etkisinin belirleyici bir faktör olmadığı ortaya çıkmaktadır.

Anahtar Kelimeler: *Vergi Uyumu, Vergi Kaçakçılığı, Birey-Tabanlı Modelleme, NetLogo*

Introduction

Tax compliance is described as 'the degree to which a taxpayer obliges to tax rules and regulations' (Alabede *et al.* 2011). In a broader sense, tax compliance is an individual and a social phenomenon which determines -and probably reflects- the success of a tax system for raising revenue. Therefore, analyzing tax compliance behavior of taxpayers is crucial especially for designing an efficient tax system.

In this paper, we develop an agent-based tax compliance model of the Turkish tax system, mainly influenced by Bloomquist (2011), which is one of the few papers that analyze tax compliance using agent-based simulation. Our simulations results show that the specifications that are employed in our model produce results that closely reproduce actual compliance rates in Turkey.

The outline of the rest of this paper is as follows. In the next section we review the literature on tax compliance with a focus on standard microeconomic theory and agent-based simulation, respectively. In the third section we introduce our agent-based model. Data on Turkish taxpayers is described in section four. In section five we present simulation scenarios and results of our model implementation. The final section concludes.

Literature Review

Since Allingham and Sandmo (1972) the tax compliance behavior of individuals has been viewed from an evasion perspevtive. In their paper Allingham

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and Sandmo assert that the extent of tax evasion is determined by the existing system of control and penalties which defines expected costs and benefits of tax evasion. Intense monitoring activities and higher penalty rates for tax evaders lead to a decrease in tax evasion. Hence tax compliance behavior of a taxpayer depends on the probability of being detected, penalty rate, marginal tax rate, the relative size of tax base and the costs of behavioral adjustments. This neo-classical approach of tax evasion is also accepted by Srinivasan (1973) and, with little modification, Yitzhaki (1974).

The tax compliance literature has become more fruitful since the late 1970s because of the emergence of new studies that have used experimental and psychological methods such as Friedland *et al.* (1978), Kahneman and Tversky (1979), Spicer and Becker (1980) and so on, as well as an increase in studies that have employed varieties of the mathematical model of Allingham and Sandmo. Since then, the total number of studies on tax compliance and related concepts has increased dramatically. According to James and Edwards (2010), the total number of these studies has reached 987 as of October 2010. Even though the abundance and diversity of these studies keep us from drawing an abstract conclusion about tax compliance, it is usually asserted that the most important determinants of tax compliance behavior of taxpayers are economic factors such as income level, audit probabilities, tax rate, tax benefits, penalties and fines, and non-economic factors such as attitudes toward taxes, personal, social and national criteria, perceived fairness of tax system (See, e.g., Barbuta-Misu 2011).

However, the increasing popularity of agent-based simulation since the 1990s has led to some changes in economics and other social sciences including tax compliance. Agent-based modeling is a modeling approach that enables one to build models where individual entities and their interactions are directly represented. In addition, agent-based modeling stands near mathematical and statistical modeling in terms of its rigor (Gilbert 2008).

The first agent-based tax evasion (compliance) model was constructed by Mittone and Patelli (2000). They examine the effects of initial mix of taxpayers on tax evasion in cases of no audits and uniform auditing. Their model defines taxpayers as honest, imitative and perfect free rider, and concludes that, with little enforcement activity, and even with some amount of honest taxpayers, all agents converge to 'almost total evasion behavior'. Davis *et al.* (2003) defines taxpayers as honest or evader and concludes that tax authority might use enforcement measures as a tool to prevent tax evasion rather than as a tool to augment effective tax compliance level.

On the other hand, Antunes and his colleagues analyze tax compliance behavior of individuals using multi-agent based approach in several papers, e.g., Antunes *et al.* (2006, 2007a, 2007b). Antunes *et al.* (2006, 2007a) argue that, for individuals, some ideas and facts such as trust, peer perception, social imitation, enforcement of local neighbourhood and reputation are more important than maximizing expected utility. Antunes *et al.* (2007b) highlights micro-level motivations interacting with macro-level results in the context of tax compliance in indirect taxes, and concludes with a general evaluation that social simulation with heterogeneous individual agents is well suited to portray the complex nature of the individual's tax compliance decision.

Korobow *et al*. (2007) models the effects of weighting neighbours' payoffs on taxpayer agents. They find that for a given enforcement system, a society which has limited knowledge of neighbour payoffs seems to lead to higher levels of aggregate tax compliance than when agents are conscious of neighbour strategy payoffs and factor these into their individual tax compliance decisions.

Hokamp and Pickhardt (2010) analyze evolution of income tax evasion under alternative tax policies in an agent-based model with heterogeneous agents. Their paper categorizes taxpayers as utilitarian, imitative, moralist and random, and the findings assert that ethical norms and lapse of time effects reduce the extent of tax evasion particularly strongly.

As the inspiring study for our paper, Bloomquist (2011) designs an agent-based model of small business taxpayer reporting compliance based on agent-based evolutionary coordination model, and defines taxpayers as honest, strategic, defiant and random. Simulation results show that after several time periods the initial number of honest taxpayers declines and the number of both defiant and strategic taxpayers increases. Bloomquist (2011) also asserts that neighbours' behavior is not a key factor on compliance behavior of taxpayers in the real world. We give further details about agent-based tax compliance model of Bloomquist (2011) in the next section.

A second group of agent-based tax evasion models has come from econophysics, a relatively new field of physics. For example, Lima and Zaklan (2008), Zaklan *et al.* (2008), Zaklan *et al.* (2009) have all employed agent-based tax evasion models that based on Ising model which is a mathematical model of ferromagnetism, developed by the physicist Ernst Ising in 1925. Ising model is used to imitate cooperation among agents in agent-based modeling of tax evasion, and shows that tax evasion may be restricted by using punishment as an enforcement mechanism. In addition to this conclusion which is also common for nearly all agent-based models, Ising model has an exogenous (independent) variable as "temperature" that concurrently effects all agents. Recently, Pickhardt and Seibold (2011) have re-interpreted temperature as a global influence such as public goods.

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 defiants (i.e. malevolent agents with fully incompliant tax reporting behavior), honests (i.e. benevolent agents with fully compliant tax reporting behavior), strategics and randoms. 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) language. 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:

$$EU(x) = (1-p)(y-tx)^{\alpha} + p\left[y - ty - \phi(ty - tx)\right]^{\alpha} \quad (1)$$

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 $p < \frac{1}{1+\phi}$ 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 behave fully compliant no matter belongs to which archetype.

The model implements perceived auditing and neighbourhood 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.

Similarly, neighbourhood 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 (von Neumann) neighbourhood 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.

Turkish Data

Data used in implementing our model come primarily from annual reports produced by the Turkish Revenue Administration. As seen in Table 1 below, the data is for a term of five years (2006 to 2010). We use total numbers of active taxpayers and numbers of audits to calculate *actual audit rate* for this term. We also use data of audited tax base and detected tax base differences for calculating *compliance rate*. Using Revenue Administration's data on active taxpayers and taxpayers who left tax liability, then, we find *attrition rate*. Finally, we calculate *effective tax rate* of Turkish tax system by using data on GDP and total tax revenues of Turkey. We use arithmetical means of *actual audit rates*, *compliance rates*, *attrition rates*, and *effective tax rates* in our simulation model.

Table 1. Turkish Tax Data for the 2006-2010 Period

Year	No. of active taxpayers	No. of audits	Actual audit rate (%)	Compliance rate (%)	Attrition rate (%)	Effective tax rate (%)
2006	3,937,878	110,442	2.804	49.67	13.34	19.9
2007	4,027,665	135,847	3.373	67.56	11.77	20.3
2008	4,035,013	113,073	2.802	27.20	13.13	20.0
2009	4,103,587	47,787	1.165	56.18	12.29	20.6
2010	4,248,942	50,348	1.185	16.67	12.00	21.4
Mean:			2.266	43.46	12.51	20.4

Source: Gelir Idaresi Baskanligi (Revenue Administration), Annual Reports of the years 2006, 2007, 2008, 2009, 2010; Gelir Kontrolorleri Dernegi (Association of Revenue Auditors), www.gkd.org.tr

Simulation Scenarios and Runs

We set *income distribution* as 'uniform' and taxpayer *selection strategy* for audit as 'half-half' position. We also set *actual audit rate* as 0.023, *gamma* value as 0.63, *phi (penalty)* value as 0.50, *effective tax rate* as 0.20, *attrition rate* as 0.13. In addition to these values, we set *chance of bankruptcy* and *non-bankrupt leaver rate* for agents (taxpayers) as 0.80 and 0.25, respectively.

We have four agent-based simulation scenarios on tax compliance for Turkey. In the first scenario, our simulation model is adjusted to both *neighbourhood effect* and *perceived auditing effect* 'off' positions as seen in Fig. 1. Fig. 2 gives the results of the first scenario. When we run the first scenario for hundred time periods, this scenario generates a mean compliance rate of 0.40 while real compliance rate for Turkey is

0.43 as given in Table 1. This result means that mean compliance rate of this scenario converges to real compliance rate for Turkey. Also, this run indicates that the compliance rate dispersions at the beginning and at the end change. For instance, the frequency of agents in between 0-10 % compliance rate dispersion decreases from 6,016 to 4,617. Similarly, the frequency of agents in between 90-100 % compliance rate dispersion decreases from 2,388 to 2,229.

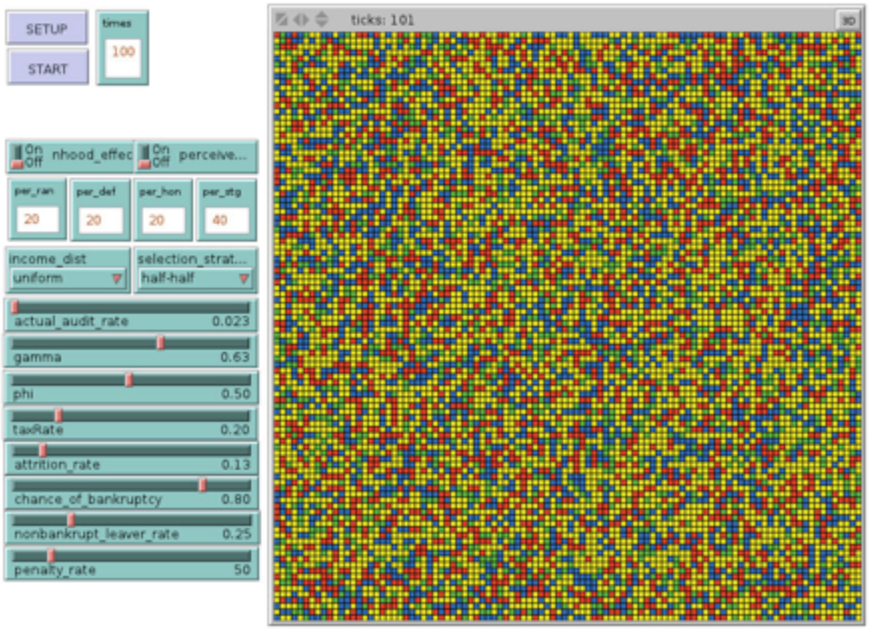

Figure 1. Screen Capture of the First Scenario Interface

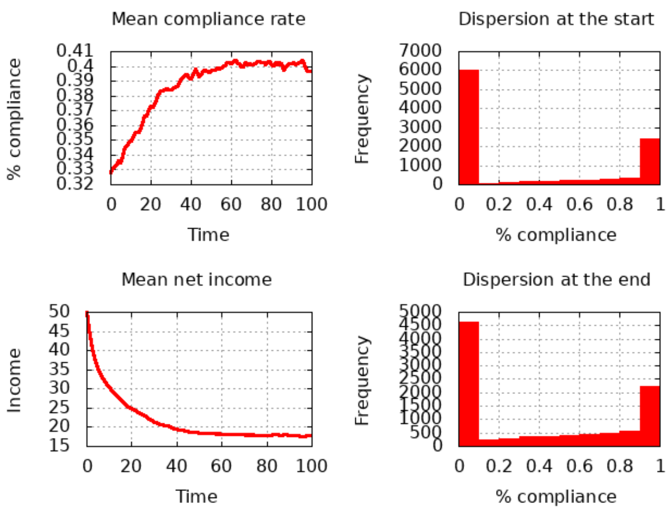

Figure 2. The Results of the First Scenario

In the second scenario, we adjusted our model to *neighbourhood effect* 'off' and *perceived auditing effect* 'on' positions as seen in Fig. 3. Fig. 4 gives the results of the second scenario. When we run this scenario for hundred time periods, we see that this scenario produces a mean compliance rate of 0.50 which is greater than mean compliance rate of the first scenario (0.40). However, this value is also not far from real compliance rate for Turkey as 0.43. This run also shows that the compliance rate dispersions at the beginning and at the end are different. For example, the frequency of agents in between 0-10 % compliance rate dispersion decreases from 6,019 to 3,765. But the frequency of agents in between 90-100 % compliance rate dispersion increases from 2,370 to 3,501.

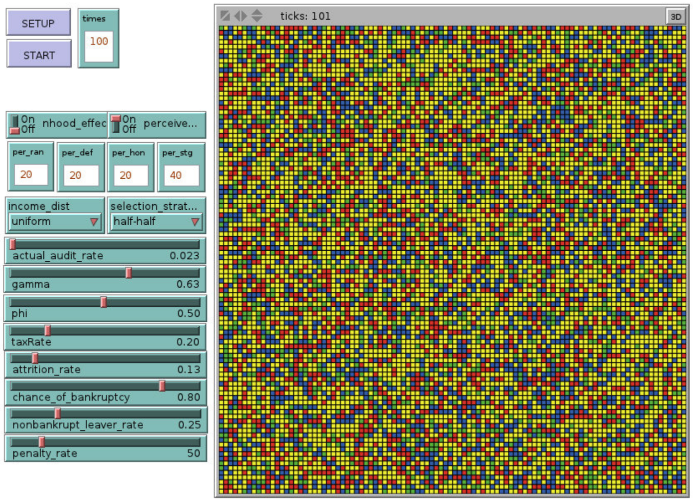

Figure 3. Screen Capture of the Second Scenario Interface

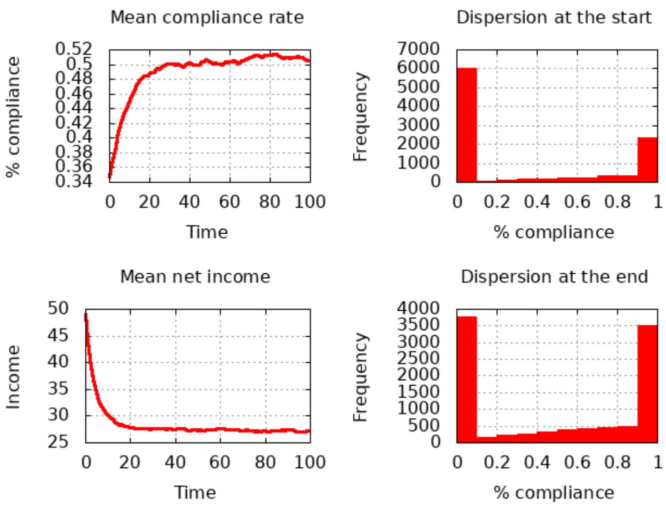

Figure 4. The Results of the Second Scenario

We adjusted our model to both *neighbourhood effect* and *perceived auditing effect* 'on' positions in the third scenario as seen in Fig. 5. Also, Fig. 6 gives the results of the third scenario. When we run the third scenario for hundred time periods, we see that this scenario generates a mean compliance rate of 0.15, the minimum mean compliance rate of all the four scenarios. In this run, the compliance rate dispersion at the beginning and at the end differ too. For instance, the frequency of agents in between 0-10 % compliance rate dispersion increases from 6,015 to 8,439. But the frequency of agents in between 90-100 % compliance rate dispersion decreases from 2,376 to 1,358.

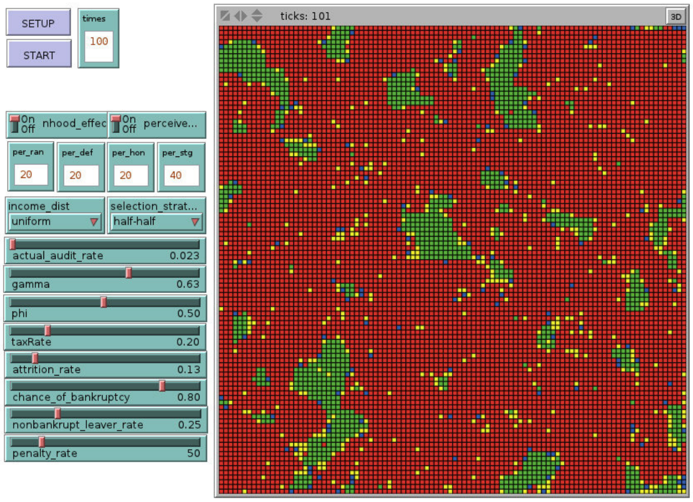

Figure 5. Screen Capture of the Third Scenario Interface

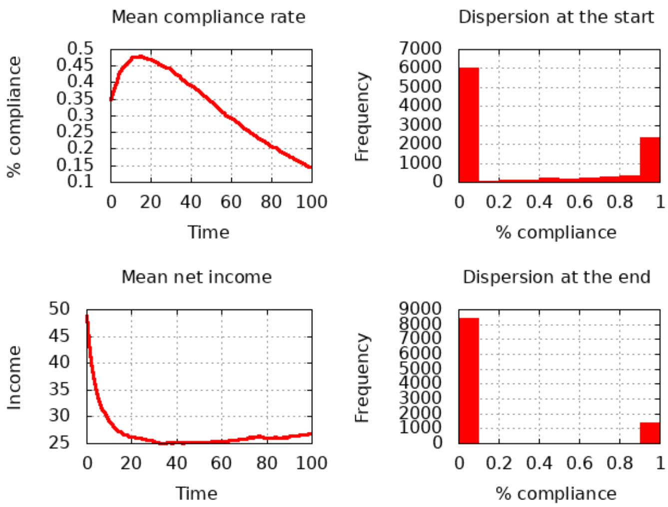

Figure 6. The Results of the Third Scenario

In the last scenario, we adjusted our model to *neighbourhood effect* 'on' and *perceived auditing effect* 'off' positions as seen in Fig. 7. Fig. 8 also gives the results of the fourth scenario. When we run this scenario for hundred time periods, it is seen that this scenario produces a mean compliance rate of 0.22. Similarly, this run points out that the compliance rate dispersions at the beginning and at the end have different values too. For example, the frequency of agents in between 0-10 % compliance rate dispersion increases from 6,021 to 7,608. However, the frequency of agents in between 90-100 % compliance rate dispersion decreases from 2,385 to 2,000.

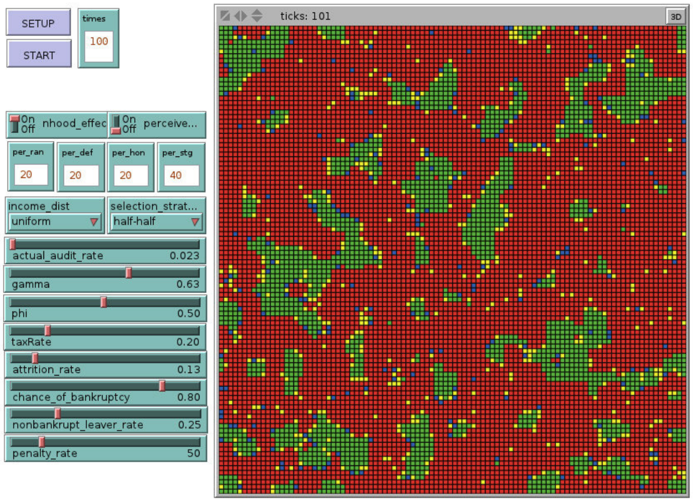

Figure 7. Screen Capture of the Fourth Scenario Interface

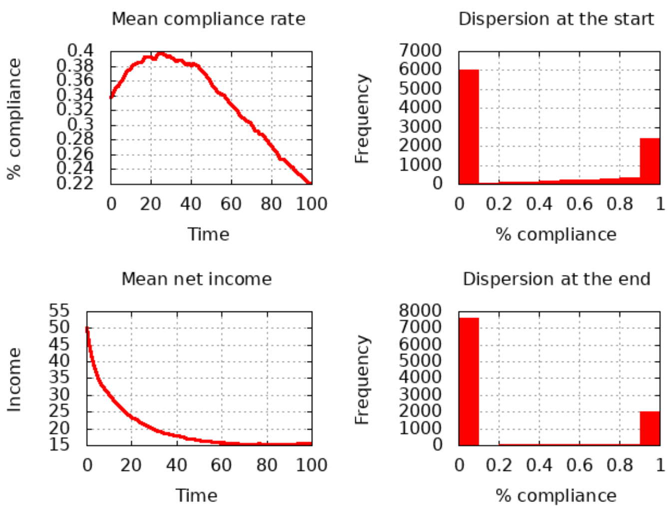

Figure 8. The Results of the Fourth Scenario

Conclusion

In our paper, we develop an agent-based tax compliance simulation model for Turkish tax system, mainly influenced by Bloomquist (2011). Our model introduces four tax compliance scenarios that run as (a) both *neighbourhood effect* and *perceived auditing effect* 'off' positions, (b) *neighbourhood effect* 'off' and *perceived auditing effect* 'on' positions, (c) both *neighbourhood effect* and *perceived auditing effect* 'on' positions, and (d) *neighbourhood effect* 'on' and *perceived auditing effect* 'off' positions. These runs yield interesting results as given below.

First of all, the first and the second scenarios (which run *neighbourhood effect* 'off' positions) produce mean compliance rates of 0.40 and 0.50 respectively that can be thought as lower and upper ranges of Turkey's real mean compliance rate of 0.43. Especially the first scenario (which run both *neighbourhood effect* and *perceived auditing effect* 'off' positions) seems almost fit to the real Turkish compliance rate. That means this scenario can easily be run in real life for re-designing and/or arranging tax policy of the government.

On the other hand, the results of the third and fourth scenarios (which run *neighbourhood effect* 'on' positions) clearly points out for Turkish case that *neighbourhood effect* is not a realistic factor for explaining tax compliance behavior of taxpayers just as set forth by Fortin *et al.* (2007), Korobow *et al.* (2007), and Zaklan *et al.* (2009). Both scenarios generate mean compliance rates of 0.15 and 0.22 respectively. Their results mean that in case of low actual auditing rate, even penalty rates considerably high, *neighbourhood effect* drives the population to the advantage of defiant agents, as Bloomquist (2011) arrived similar findings. These values are far from Turkish mean compliance rate of 0.40 and can be qualified as unrealistic for Turkish case.

More interestingly, we find an evolutionary process in the scenarios with *neighbourhood effect* 'off' (the first and the second scenarios). To the effect that, compliance rate histogram dispersions other than the columns of 0-10 % and 90-100 % increase at the end to the beginning. Thus, strategic and random agents become more compliant. This result imply that there is an evolutionary adaptation process in tax compliance behavior of agents.

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