



# Income tax evasion dynamics: Evidence from an agent-based econophysics model



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## ABSTRACT

We analyze income tax evasion dynamics in a standard model of statistical mechanics, the Ising model of ferromagnetism. However, in contrast to previous research, we use an inhomogeneous multi-dimensional Ising model where the local degrees of freedom (agents) are subject to a specific social temperature and coupled to external fields which govern their social behavior. This new modeling frame allows for analyzing large societies of four different and interacting agent types. As a second novelty, our model may reproduce results from agent-based models that incorporate standard Allingham and Sandmo tax evasion features as well as results from existing two-dimensional Ising based tax evasion models. In this way, such kind of models may become more relevant and useful in economics as well as social psychology. We finally use our model for analyzing income tax evasion dynamics under different enforcement scenarios and point to some policy implications that may also be of interest for psychological research on tax compliance.

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## 1. Introduction

Agent-based tax evasion models have gained much popularity over recent years because they allow for analyzing tax compliance behavior in large populations of heterogeneous agents that interact with each other in a direct manner (see e.g. Korobow, Johnson, & Axtell, 2007). Moreover, these models can take a high degree of complexity into account; for example, by simultaneously incorporating various policy parameters of the government, by endowing each individual agent with a different set of attributes regarding income, risk aversion, etc. or by calibrating individual agent behavior with a diversity of different individual human behavior patterns, which may have been discovered in tax evasion experiments with human subjects, in fields such as economic psychology or by empirical analysis (see e.g. Alm, McClelland, & Schulze, 1992; Alm, 2012; Andreoni, Erard, & Feinstein, 1998; Kirchler, 2007). To this extent, and in contrast to traditional models, agent-based tax evasion models enable the analysis of tax evasion dynamics in a fairly realistic way, which in turn may lead to new insights and policy options for combating tax evasion.

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In this paper, we develop and analyze an agent-based tax evasion model that is based on a standard model of statistical mechanics, the Ising model of ferromagnetism. Among other things, the model allows for the numerical simulation of tax evasion dynamics in very large populations of heterogeneous agents, where heterogeneity refers to several different behavioral patterns. We show that our model reproduces previously published results obtained from fundamentally different types of agent-based models. We then use the model for analyzing tax evasion dynamics that follow from alternative enforcement scenarios to combat tax evasion. For example, we find that (i) there is a certain threshold for efficient audits, (ii) real world audit rates may be too low to effectively curb tax evasion, (iii) the distribution of behaviorally heterogeneous agent-types in the society matters for audit efficiency, and (iv) direct agent interaction may effectively be a substitute for monetary penalty payments.

The paper is organized as follows. In Section 2 we provide some background on standard income tax evasion theory and existing agent-based tax evasion models. In Section 3, we develop the econophysics model of tax evasion and apply it to an analysis of audit efficiency and for some replication studies. Concluding remarks are provided in the final section.

## 2. Background

In this section we briefly compare and contrast the standard approach to income tax evasion with essential features of agent-based tax evasion models. Next, we review a few of these settings including some econophysics frameworks which are based on the Ising model of ferromagnetism and which we use in section three for constructing a novel agent-based tax evasion model.

### 2.1. Modeling income tax evasion

The neoclassical standard approach to income tax evasion considers a representative, self-reporting agent who declares an income  $X$  so as to maximize expected utility,  $EU$ , according to,

$$EU[X] = (1 - p)U[W - \theta X] + pU[W - \theta X - \pi(W - X)], \quad (1)$$

where  $W$  denotes the true income (or wage) of the representative agent,  $\theta$  is the tax rate on declared income and  $\pi$  is the tax rate on undeclared income, where  $\theta < \pi$  indicates a monetary penalty on income tax evasion and  $p$  is the audit probability, with  $0 \leq p \leq 1$  (Allingham & Sandmo, 1972; Srinivasan, 1973).  $U[X]$  denotes the utility function where, given this modeling frame, risk neutral taxpayers (i.e.  $U[X]$  is a linear function) declare their full income if  $(\theta/\pi) < p$ , but declare nothing at all if  $(\theta/\pi) > p$ . In contrast, risk-averse taxpayers (i.e.  $U[X]$  is a concave function) may declare their income fully, partly or not at all. Other things being equal, the more risk-averse a taxpayer is, the more compliant a tax-payer will be and both absolute and relative risk-aversion may play a role for the extent of tax evasion. Hence, in the standard income tax evasion model risk aversion is the driving force that allows for interior solutions. Of course, subsequent literature has developed various extensions and alternatives. For example, all-or-nothing decisions of risk-neutral taxpayers may be avoided, if the audit probability is an increasing function of the amount of undeclared income (Yitzhaki, 1987), or if there are two or more income sources each having a different audit probability. Further, the penalty may be proportional to unpaid taxes (Yitzhaki, 1974), which ensures that an increase in the marginal tax rate results in an increase of reported income.

In any case, essential features of the neoclassical standard approach to tax evasion are: (i) each agent has perfect knowledge about his own expected utility function and the relevant parameter values, which allows him to maximize his own expected utility, (ii) the mathematical specification of the utility function leads to situations where the agent maximizes his expected utility either by an all-or-nothing decision or by an interior solution in which the agent may declare just some part of his true overall income, (iii) heterogeneity in agent behavior may be introduced by individualizing one or more parameter values that enter an agent's expected utility function, (iv) dynamics in the behavior of agents can be due to parameter changes only, (v) any kind of direct interaction among the agents is ruled out.

Agent-based tax evasion models deviate from the neoclassical standard approach in at least three ways. A feature that distinguishes any agent-based tax evasion model from the neoclassical approach is the direct interaction among agents. In particular, the behavior of all or at least some agents depends on the behavior shown by a well specified subgroup of other agents, say neighbors, within the same model. Besides this type of interaction is non-market based. Another important difference is that some agents, if not all agents, may not possess an utility function. Finally, in agent-based models tax evasion dynamics may be triggered by either parameter changes or by stochastic processes or a combination of both.

Although agent-based tax evasion models are a comparatively new tool for analyzing tax compliance issues, substantial differences already exist between these models or model types. Therefore, in the next subsection we briefly review the literature on agent-based tax evasion models.

### 2.2. Agent-based tax evasion models

As noted, the essential feature of any agent-based model is the direct non-market based interaction of agents, which is combined with some process that allows for changes in individual behavior patterns. The role of social interactions for economic behavior has been reviewed by Brock and Durlauf (2001) and its connection with tax evasion has been pointed out by

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