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An agent based model for studying optimal tax collection policy using experimental data: The cases of Chile and Italy

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ABSTRACT

This paper investigates optimal audit programs in an economy populated by artificial agents. The behavior of the artificial agents is calibrated using data obtained from experiments on fiscal evasion made in northern Chile (Antofagasta) and northern Italy (Trento). We identify a tax collection policy that is optimal in the sense that its outperforms the tax payments made by the calibrated agents, using any other standard collection plans used by governments. We find that the design of an optimal audit scheme depends on three components: income distribution, the identification of patterns of behaviors and the number of times individuals are audited.

1. Introduction

According to Galetovic et al. (2001) tax evasion in Chile in 1999 was about 6% of GDP, while tax collection was 18% of GDP. In Italy, the hidden economy figure in 1998 was about 27.8% of GDP (see Schneider, 2000). The aim of an institution that enforces tax laws is to design a taxation system, audit programs and a punishment scheme that meet revenue objectives. The efficiency of the program improves government revenues and reduces tax evasion.

This paper is about the optimal design of an audit program for improving the net revenue of the government, given a tax and punishment scheme. We explore the audit program in an economy populated by artificial agents, where the behavior of the artificial agents is calibrated using data from experiments conducted in Chile and Italy.

Modeling audit programs means modeling the behavioral interaction between taxpayers and the tax authority. There are two lines of research for understanding tax audit selection decisions. On the one hand there is empirical work to determine what makes the audit more likely, given the characteristics of the taxpayers, and on the other hand, there is a more extensive literature on theoretical models describing the optimal audit rules, considering specific behavioral assumptions of the agents.

The empirical literature shows that the likelihood of an audit is correlated to the values of certain tax return line items. According to the review by Erard et al. (1998), reports of capital income or a large tax liability increase the chance of being audited. Moreover, tax agencies possess private information not recorded in the available tax return that plays an important role in audit selection. As indicated by the authors, this information correlates very well with actual noncompliance detected during audits.

Theoretically, models of optimal taxation and audit programs differ in terms of the assumptions about taxpayers and the tax authority. As suggested by Sandmo (2005), the decision of one taxpayer might be affected by those of other taxpayers. It is more costly to be honest in a country where corruption is common, or similarly, it may be less risky to evade taxes in a country where evasion is widespread. As shown in Andvig and Moene (1990), in order to model these effects, a theory of social interaction is required. The design of an optimal plan in this context requires a treatment of social effects.

Most models on optimal taxation consider an individual representative taxpayer, and the optimal taxation problem is posed as that of choosing a set of instruments to maximize a measure of social welfare subject to budgetary constraints. This question is solved in the framework of a principal-agent problem, as in Reinganum and Wilde (1985) where it is assumed that the government commits itself to an audit rule, or in the framework of game theory, as in Reinganum and Wilde (1986), where the government does not commit itself to a rule and the agents make decisions sequentially.

In this paper, we populate an artificial economy with a set of artificial agents. The behavior of taxpayers is calibrated according to the pattern of behavior observed in two experiments on fiscal evasion conducted in northern Chile (Antofagasta) and northern Italy (Trento). We define a proportional tax for all the agents in the economy, and the purpose of the paper is to identify an

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optimal control plan, i.e. the frequency of audits for every agent in the economy so that the government obtains an optimal collection of taxes in the economy.

Following Homer and Denis (1988), we assume that the tax authority is a revenue-maximizing agency. The agency can earn high net revenues by doing a good job, firstly on collecting revenue and secondly on deterring underpayments that threaten to undermine self-enforcement.

We use the theory of finite automata for capturing the experimental behavior of subjects and integrate this into the simulated model because it provides us with a dynamic explanation of agent behavior. Working with finite automata means that we assume that an individual decides whether to evade or not according to the state where she is. For instance, evasion might be very likely when an individual is in the state "audited in the previous period", or in the state "audited and fined three periods ago". The standard expected utility model of the income reporting decision discussed in Allingham and Sandmo (1972) or more behavioral alternatives, such as that presented by Dhami and Nowaihi (2007) using Prospect Theory, do not take into account the changes in individual state as a consequence of the interaction with the tax authority.

We organize the paper by first presenting the structure of our artificial economy. We then present the experiments carried out in Chile and Italy. Through a short introduction to the theory of finite automata we show how we captured the behavior of the subjects in the experiments. Following this, we run the simulated experiments and analyze the results. Finally, we discuss the most relevant features of our experiment and make our conclusions.

2. The model

In our economy time evolves in discrete periods $t = 1 \ldots T$. In every period there is an exogenously given level of production of the economy Z. This production is distributed among the population N of individuals populating in the economy. In every time period, each individual i receives an income of y_i, which is the same for all the periods T for the individual i.

The production of the economy is distributed according to the distribution rule distribution $Y(N, \cdot)$. Given the income distribution $Y(N, \cdot)$, the income of the agent i is $y_i = Y(N, i)$. As a particular case, income distribution $Y_0(N, \cdot)$ represents the distribution where all the agents receive the same income. In other words, $G(Y_0(N, \cdot)) = 0$, where the $G(\cdot)$ is the Gini Index of income distribution. Note that in every period $Z = \sum_{i=1}^{N} Y(N, i)$

At the beginning of every period, each agent receives the income y_i and faces a tax rate of τ. She has to decide whether or not to pay the total amount τy_i.[1] We assume that every individual i uses a choice function $a_i(\cdot, t)$ to decide whether or not to evade taxes. We represent the choice function by a finite automaton calibrated by the results obtained in the experiments for the cases of Chile and Italy. This will be explained in more detail below.

The government in every period of time selects a subset of individuals from the population to be audited. We denote by $S(N, t)$ the rule used by the government to select individuals from the population N at period t.

Because there are decreasing economies in the number of audits by the government, it is not possible to audit all the individuals of the population.

The government wants to find a selection rule $S(\cdot, \cdot)$ that optimizes the collection of taxes across the T periods.

[1] Note that in this model individuals decide whether or not to pay. In the literature on tax compliance taxpayers commonly report their incomes and decide to pay tax according to reported incomes. We make our agents decide how much to pay because we are following the design of the experiments in Italy and Chile.

Formally we can express the government problem as the maximization of net revenue defined by,

$$R(x) = \sum_{t=1}^{T} \frac{1}{(1+r)^t} \left(\sum_{i=1}^{N} a_i(y_i, t) - C(\sharp S(N, t)) + \sum_{i \in S(N,t)} f_i(a_i(y_i, t)) \right) \quad (1)$$

where $a_i(\cdot, \cdot)$ is the choice function to decide the tax to be paid used by the agent i. $C(\sharp\, S(N, t))$ is the cost of auditing the number of agents suggested by the selection rule $S(N, t)$ at time t[2] and finally $f_i(a_i(y_i, t))$ is the fine payed by the agent i if he evaded tax and was audited during the period t.

We represent the rule $S(N, t)$ as a binary string of size N. If the string $S(N, t)$ has a '0' in the position $1 \le i \le N$, this means that the agent i is not audited in the period t. Similarly, if the string $S(N, t)$ has a '1' in the position $1 \le j \le N$, this means that the agent j is audited in the period t.

Note that the rule $S(N, \cdot)$ represents the plan of the government for the T periods. The bit, $(t-1)N + i$ of the plan $S(N, \cdot)$ indicates whether the agent i is audited or not during the period t.

For the sake of this exposition, we suppose that our economy has $N = 3$ agents and the government has evaluated its tax collection plan for a horizon of $T = 3$ years. In this case, a plan represented by $S(N, \cdot) = 100100100$ indicates that in the three periods only the first agent will be audited.

The problem for the government is to find the plan $S^*(N, \cdot)$ so that,

$$S^*(N, \cdot) = arg \max_{S(N, \cdot)} R(x) \quad (2)$$

The behavior of the N agents populating the economy is calibrated according to the data obtained from the experiments to be explained below. Each agent has a memory, so every time the government controls one of them, his behavior is modified. This makes the problem of searching for the optimal plan nonlinear.

In the following section, we present the experiments, and the method used for capturing the behavior of the subjects. We specify how we simulate the choice function $a_i(\cdot, t)$ to decide whether an agent evades taxes or not during a period t.

3. The experiments

The experiments discussed in this work were carried out using an identical experimental design – software, instructions, payoff structure – in Italy at the CEEL laboratory of Trento University and in Chile at the Catholic University of the North. The experiments are best described and discussed in Mittone (2006) and Garrido and Mittone (2008).

There are three type of experiments: the baseline experiment and two alternative treatments. The baseline experiment is based on a repeated choices setting and is designed as a benchmark for the other two experiments. Treatment one introduces a mechanism of redistribution of the tax yield among the participants, while treatment two uses the tax yield collected to finance the production of a public good that is consumed outside the subjects participating in the experiments. The hypothesis tested with treatments one and two is that the sentiments of others might change tax evasion *ceteris paribus*.

The baseline session, as well as the treatment sessions, were run using a computer-aided game. Thirty undergraduate students participated in each session, 15 men and 15 women. All the

[2] Note that $\sharp$ count the number of audited agents by the rule $S(N, t)$.