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Printed: ISBN: 978-0-9564944-4-3 **European Council for Modelling**

CD: ISBN: 978-0-9564944-5-0 **and Simulation**

Coverpicture **© Koblenz-Touristik**

printed by **Digitaldruck Pirrot GmbH**

66125 Sbr.-Dudweiler, Germany

PROCEEDINGS
26th European Conference on Modelling and Simulation ECMS 2012

May 29th – June 1st, 2012
Koblenz, Germany

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Michael Möhring
Ulf Lotzmann

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Hosted by:
University of Koblenz-Landau

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PREFACE

The natural and the artificial environment of mankind is of enormous complexity, and our means of understanding this complex environment are restricted unless we make use of simplified (but not oversimplified) dynamical models with the help of which we can explicate and communicate what we have understood in order to discuss among ourselves how to re-shape reality according to what our simulation models make us believe to be possible. Being both a science and an art, modelling and simulation is still one of the core tools of extended thought experiments, and its use is still spreading into new application areas, particularly as the increasing availability of massive computational resources allows for simulating more and more complex target systems.

In the early summer of 2012, the 26th European Conference on Modelling and Simulation (ECMS) once again brings together the best experts and scientists in the field to present their ideas and research, and to discuss new challenges and directions for the field.

The 2012 edition of ECMS includes three new tracks, namely Simulation-Based Business Research, Policy Modelling and Social Dynamics and Collective Behaviour, and extended the classical Finance and Economics track with Social Science. It attracted more than 110 papers, 125 participants from 21 countries and backgrounds ranging from electrical engineering to sociology.

This book was inspired by the event, and it was prepared to compile the most recent concepts, advances, challenges and ideas associated with modelling and computer simulation. It contains all papers carefully selected from the large number of submissions by the programme committee for presentation during the conference and is organised according to the still growing number tracks which shaped the event. The book is complemented by two invited pieces from other experts that discussed an emerging approach to modelling and a specialised application.

We hope these proceedings will serve as a reference to researchers and practitioners in the ever growing field as well as an inspiration to newcomers to the area of modelling and computer simulation. The editors are honoured and proud to present you with this carefully compiled selection of topics and publications in the field.

Klaus G. Troitzsch	Michael Möhring	Ulf Lotzmann
General Conference Chair and Programme Chair	Conference Co-Chair	Programme Co- Chair

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EXPLORING TAX COMPLIANCE: AN AGENT-BASED SIMULATION

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KEYWORDS

Tax Compliance, Decisional mechanisms,
Computational Economics, ABM Simulation.

ABSTRACT

This paper is just a concept presentation to be discussed at the ECMS12, based on preliminary work of a research project funded by the Spanish Institute for Fiscal Studies (Ministry of Economy). This project aims to build an agent-based model (ABM) for the simulation of tax compliance and tax evasion behaviour, and to calibrate it empirically in order to generate some known patterns of tax behaviour among Spanish taxpayers. Here we present the state of the development for the formal model and our present ideas about the implementation methodology, with focus on a new algorithm -based in four different decisional mechanisms- so that it includes not just the usual *expected utility optimization*, but also other sociologically relevant features like social network structure, social influence, decisional heuristics, biases in the perception of the tax system, and heterogeneity of tax motivations and tax morale among the agents. The methodological discussion about this kind of "modularity" in implementing a decisional engine could be completed in Koblenz with some preliminary results based on experimentation with the initial parameters and decisional modules.

INTRODUCTION

Tax evasion, -voluntary reduction of the tax burden by illegal means- is a problem of great social relevance. This is because, (a) it reduces the resources available to the public sector, a fact that is especially hard in the case of Spain, whose "underground" economy is, by some estimates, around 20% of the GDP; and (b) tax fraud, which do not extends homogeneously among all taxpayers, causes that the tax system violates *de facto* the principles of justice, equality and progressiveness. Try to understand the causes and determinants of heterogeneity in tax evasion, both temporal and geographic, appears as a relevant task as long as it should contribute to the design of institutional strategies that ultimately make possible to prosecute such evasion and therefore contribute to improving effective justice system and increase tax revenues without increasing tax rates. This fact is particularly interesting when taking into account the difficulties that governments are experiencing in recent times in maintaining a balanced budget and therefore maintaining welfare-state policies. That is the case of Spain, where the level of tax evasion is, according to different estimations, very high, while the level of tax morale is quite low. This pattern is specially harming in the present context of fiscal crisis and scarcity of public resources.

STATE OF THE ART

Scientific research of tax evasion dates back to the model developed by Allingham and Sandmo (1972), and, in parallel, by Srinivasan (1973), based on neoclassical economic theory. This model is an adaptation of the "crime economics" by G. Becker, an attempt to explain deviant behavior in terms of rational choice: the individual decides how much of their income he should declare in relation to the benefits of hiding (because the tax rate) and the costs of being discovered (given the probability of inspection and the amount of the fine). The main criticism launched against this approach was that predicted a much higher level to the observed tax evasion: given the low probability of inspection and the level of existing sanctions in the real world, the majority behavior should be to evading, which in fact does not happen (Alm et al., 1991). Thus, investigations of the past two decades can be seen as successive attempts to broaden the traditional neoclassical model in order to account for an act, tax compliance, which appears as "quasi-voluntary" (Levi, 1988).

Not surprisingly, in such an enterprise does occupy a prominent place those studies through opinion surveys trying to measure and to explain the tax morality (*tax morale*) of citizens, defined as "intrinsic motivation" or "internalized willingness" to pay taxes (Braithwaite and Ahmed, 2005). Such researches had proliferated recently and have as main figure in Benno Torgler, author of several dozen of these publications in the last decade. Approximation of this kind try to explain the fiscal morale taking as a proxy the *declared tolerance to tax evasion* -often from a single survey question- and including it as a dependent variable in different regression models. Thus, although results are mostly

Proceedings 26th European Conference on Modelling and Simulation ©ECMS Klaus G. Troitzsch, Michael Möhring, Ulf Lotzmann (Editors)
ISBN: 978-0-9564944-4-3 / ISBN: 978-0-9564944-5-0 (CD)

inconclusive, these studies allow us to obtain information about the correlation of fiscal morality with both sociodemographic variables (age, sex, marital status, educational level or income...) and ideological (religion, patriotism, trust in institutions, etc.., see a summary in Torgler, 2007). In Spain there have been a modest number of academic papers of this type, as those of Prieto, Sanzo and Suarez (2006), Alm and Gomez (2008), Alarcon, De Pablos and Carre (2009) and Maria-Dolores, Alarcon and Carre (2010). However, for a country where tax evasion reached alarming proportions, would certainly be desirable to take a greater number of these investigations.

Thanks to all these contributions, researchers have been increasingly assuming that the standard economic approach is insufficient to account for a phenomenon as complex as tax evasion. Therefore, in the last four decades have been publishing an increasing number of studies that try to explain tax evasion incorporating cognitive, cultural, normative, social, and other kinds of variables. These mostly adopt two methodological strategies: first, are the experimental approach of behavioral economists and psychologists, on the other hand, the aforementioned studies about "tax morale" made from opinion surveys.

Against the mainstream of those researches, can be found an incipient and small group of studies using ABM (agent-based models simulation) to explain the tax fraud at the aggregate level. These works contain models that, while assuming that tax evasion depends on the degree of deterrence (inspections and sanctions), have the key advantage of allowing the formalization of other effects, such as social interaction.

Early attempts correspond to Mittone and Patelli (2000), Davis et al. (2003) and the TCS model of Bloomquist (2004). The latter is the first work that uses a NetLogo model and represents an advance over the previous two, since it contains agents with a greater number of attributes; it is more complex in determining the probability of inspections and their effects and further validates the results obtained with real data.

Later we found the excellent EC* series of Antunes et al. (2006a, 2006b, 2007b; Balsa et al. 2006), in which increasingly complex models were developed by introducing progressive modifications over the standard economic model (e.g. adaptive agents with memory, social imitation, etc...). The most remarkable developments of these series of models are the inclusion of tax inspectors with autonomous decision capacity, and especially the proposal for an explanation of unpaid indirect taxes (sales taxes, value added taxes -VAT-, or goods and services taxes -GST-) from the collusion between buyers and sellers.

There is also the NACSM model (Korobow et al., 2007), which analyzes the relationship between tax compliance and the existence of social networks using the Moore neighborhood structure (ie, each agent has eight neighbors surrounding). More recently we find the proposal of Zaklan et al. (2008, 2009a, 2009b), whose peculiarity is to adapt the ISING physical model of the tax research: instead of particles that interact in different ways depending on the temperature, there are individuals who behave depending on behavior of their neighbors.

The TAXSIM model of Szabo et al. (2008, 2009 and 2010) presents a design specially rich in details, it includes four types of agents (employer, employee, government and tax office) and some innovative factors as the degree of satisfaction with public services -depending on previous experiences of individuals, as well as those who are in their social network-.

Finally, Bloomquist (2011) addresses the tax compliance for small business owners and models it as an evolutionary coordination game. The simulation model also is calibrated with data from behavioral experiments.

In short, the social simulation using ABM is a promising approach to a field in which, despite the abundant literature, results have been isolated and often poorly coordinated with each other, to the point of being able to say, as pointed out Kirchler that the investigation of tax evasion is "still in its infancy" (2007: xv).

METHODOLOGY

To build an ABM is a particularly adequate method for construing a model of tax behaviour which includes such parameters as social networks, social influence, heuristics and biases in the perception of the tax system, heterogeneity of tax motivations and tax morale among the agents, and other features that may generate complex social dynamics. Those factors have been traditionally neglected until very recently in the classical econometric models that aimed to explain the observed levels of tax compliance and tax morale -that is, disposition to pay taxes and tolerance towards tax evasion-.

MODEL DESCRIPTION

Parameters

The SimulFIS model presented here is empirically calibrated using the basic features of the Spanish tax system as well as survey data from the *Fiscal Barometer* of the Institute for Fiscal Studies and the *Survey of Public Opinion about Tax Policy* of the Spanish Centre for Sociological Research. We also use for this purpose a survey designed by us on Values and Attitudes on Distributive Justice, Social Benefits, and Taxes -funded by the Catalan Centre for Opinion Studies- (Noguera et al., 2011).

Some relevant setup parameters (see appendix A for the full set) include total population, proportion of workers and employers, proportion of unconditional law-abiders and unconditional evaders.

Agents

Agents are individuals, programmed as posessing certain common attributes such as income level -following a

quasi-exponential distribution-, a labour market position, beliefs about justice principles, perceptions of the tax system, and so on.
Agents are embedded in a rich social network whose characteristics can also be adjusted to different experimental configurations. The links for each agent are generated by a biased random engine to adjust the number of agent-neighbors classed as "workers" or "employers" as a function of the agent-class and the maximum number of links. So each agent is embedded into a social network, with a mix of equal and diverse class links or contacts, which locally became his own source of information about tax evasion behavior, inspections and fines.

Decisional algorithm
The decision algorithm for each agent includes four types of mechanisms -implemented as production rules- that play the role of "decision filters" (Elster, 1979:76; see also 1989:13-14). These elements are constrictions for the action along a deliberative process that generates the decision/action related with tax evasion:
(1) opportunity to evading, due to the economic and labour market position: affecting differently to the 6 typological classes generated by considering employees/(self)employers and socioeconomic level –high/medium/low-.
(2) normative and positive beliefs about the tax system: agents' decision is influenced by the principles of fairness or justice which motivate the agent -and how deeply they do- as well as by his perception of the tax system's factual satisfaction of those principles.
(3) rational choice: the agent maximizes his net income having in mind his knowledge about the tax rates, the probability of being detected if he evades, and the amount of the fines (see parameters table at Appendix A).

$$UE_i(X_i)=(1-p_i)\sqrt{(Y_i-X_i\cdot t_X+Z)}+p_i\sqrt{[Y_i-Y_i\cdot t_Y-\theta(Y_i-X_i)+Z]}$$

(4) social influence: once the decision has been made, the behaviour of the agent is sensitive to the perceived behaviour of the agents in his social network. After an evaluation of the level of fraud, the audit pressure, and the fines imposed in the close neighborhood, each agent adjusted its final behaviour.

Environment
Our model simulates the dynamics in a stylized or simplified virtual environment in which a central authority, each time turn, proceeds to collect taxes and then distributes the tax revenue through public goods (like social benefits, social investment, etc.). The central authority also implements a specific surveillance and inspection policy, and imposes fines on non-compliers. The simulated environment has been modeled with flexibility in mind, so that it could be easy for the simulation users to implement different tax systems and different policies to tackle non-compliance. The very idea of a "virtual tax laboratory" is behind such kind of implementation, considering that the project is commissioned by an end user (the *Spanish Institute for Fiscal Studies*, Ministry of Economy).

System dynamics
The general system dynamics follows this sequence:

System setup: Create agents
For each agent:
-Random Class allocation (workers/employers),
-Random Income allocation (quasi-exponential distribution, with interval probability table).
-Random Network generation (biased and constraint links)

*For each round:
--For each agent:
---Apply opportunity filter (or not)
---Apply normative filter (or not)
---Apply utilitarian filter (or not)
---Apply influence filter (or not)
--- Decision about income statement (X_i)

--For each agent:
---Collection of taxes.
---Inspections and penalties.

--For each agent:
---Payment of benefits.
---Consumption of agents (reference value: no savings, all disposable income is consumed in actual version).
---Update system and agents properties (memory, monitors, plotting, etc…).

*Next round

Outcomes
After running the model for a number of rounds to produce a relatively stable result, it can be analyzed in terms of the aggregate rate of tax evasion and the number of evaders. The simulation model allow to observe how different mechanisms may yield, from given initial conditions, different results in terms of aggregate compliance and tax evasion, by means of plotting and monitoring outcome data series.
By this time, we are still looking for more robust and reliable empirical data about Spanish tax-evasion behaviour, needed to provide validation to SimulFIS, because the final aim is accurately reproduction of actual figures of tax evasion.

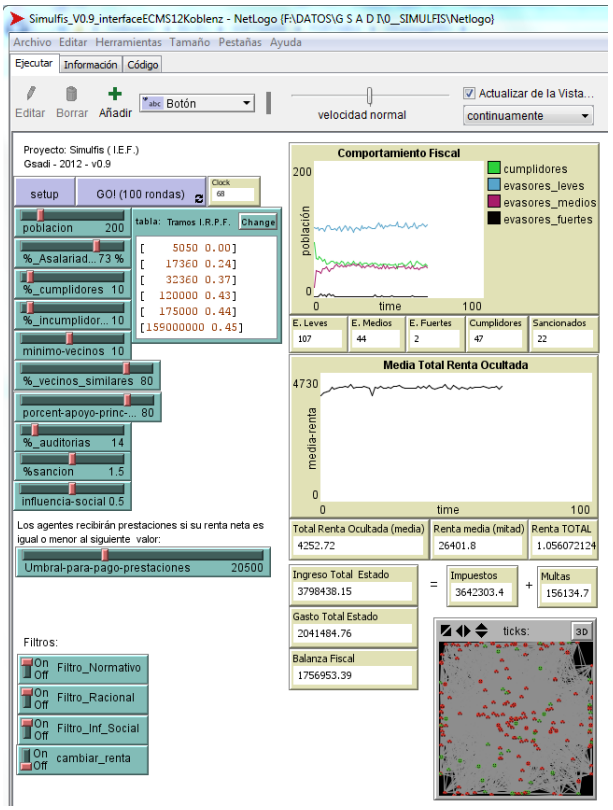

Figure 1: Screen Capture of SimulFIS interface (v0.9)

CONCLUSION AND FURTHER RESEARCH

The SimulFIS model tries to integrate some early model aspects and excellent ideas in a novel way. The "modular" decision mechanisms approach, and the parametrization of many system attributes, allows exploring both different sets of initial conditions –tax policies, tax morale, network topologies- and the relative effect of each filter over the final decision-making outcome.

Each factor, effect and mechanism here implemented has been previously proposed and explored in the relevant literature aforementioned. Added value of SimulFIS could be (1) the aim to embed it into a single model, by means of implementing the "decisional filtering" algorithm, and (2) the relevance of "network position", as the source of local cognitive scope for the decisional agents.

At the present time, the research follows on by systematically performing series of experimental design runs with the real version of the simulation model in order to obtain data to estimate the relative "strength" of each single filter –structural opportunities, normative believes rational utility expectations, and social influence-.

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ACKNOWLEDGEMENTS

This research has been funded by both the Spanish Ministry of Science and Innovation -through Grant CSO2009-09890 (I+D+i project) and CSD 2010-00034 (CONSOLIDER-INGENIO)- and the Institute for Fiscal Studies of the Spanish Ministry of Economy.

APPENDIX A

Table 1. Relevant Model Parameters

Y_i	Agent *i* Total Income
X_i	Agent *i* Declared Income
t_Y	Applicable tax rate (Y)
t_X	Applicable tax rate (X)
N	Population
p_i	Perceived probability of being fined if catch in tax-evasion, for agent *i* .
I_i^i	Tax inspections received by agent *i* in all previous rounds.
I_i^v	Tax inspections received by agent *i* neighborhood (including *i*) in previous round.
R	Total number of previous rounds
V_i	Number of neighbors of *i*
θ	Fines received by tax evasion
ω	Social influence coefficient
$UE_i(X_i)$	Expected utility of tax payment for agent *i*
Z	Public social benefits received
a_i	Rate of loopholes use for agent *i* after its rational choice in period t
a_v	Median of the rate of loopholes use in the neighborhood in the previous round
ψ	Coefficient of *"sucker-feeling"*

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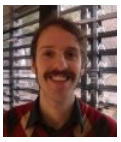

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