EXPLORING TAX COMPLIANCE: AN AGENT-BASED SIMULATION

Francisco J. Miguel
José A. Noguera
Toni Llàcer
Eduardo Tapia
GSADI - Research Group on Analytical Sociology and Institutional Design
Department of Sociology, Autònoma University of Barcelona (UAB)
Fac. Political Sciences & Sociology, Campus Bellaterra, Cerdanyola (Barcelona), 08193 Spain
E-mail: gsadi@uab.cat, Miguel.Quesada@uab.cat

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.

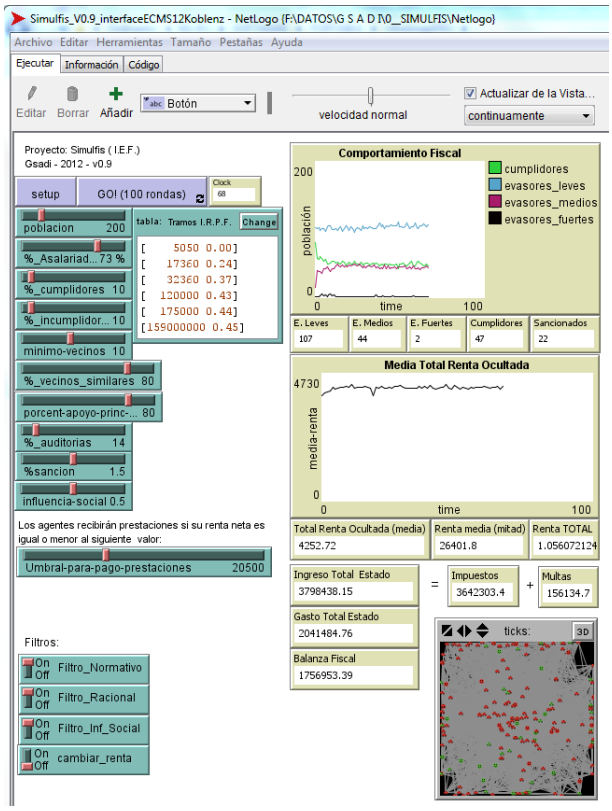


Figure 1: Screen Capture of SimulFIS interface (v0.9)

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-.

REFERENCES

Allingham, M.G. and Sandmo, A. (1972), "Income tax evasion: a theoretical analysis", *Journal of Public Economics*, 1: 323–338.

Antunes, L.; Balsa, J.; Moniz, L.; Urbano, P.; and Palma, C.R. (2006a), "Tax compliance in a simulated heterogeneous multi-agent society", in J.S. Sichman and L. Antunes (eds.): *MABS 2005*. LNCS (LNAI), vol. 3891. Heidelberg: Springer.

Antunes, L.; Balsa, J.; Respício, A. and Coelho, H. (2006b), "Tactical exploration of tax compliance decisions in multi-agent based simulation". In L. Antunes and K.Takadama (eds.): *Proc. MABS 2006*.

Antunes, L.; Balsa, J. and Coelho, H. (2007a), "Agents that collude to evade taxes". *AAMAS '07 Proceedings of the 6th international joint conference on Autonomous agents and multiagent systems*

Antunes, L.; Balsa, J. and Coelho, H. (2007b), "Tax compliance through MABS: the case of indirect taxes", *EPIA'07 Proceedings of the artificial intelligence 13th Portuguese conference on Progress in artificial intelligence.*

Balsa, J.; Antunes, L.; Respício, A. and Coelho, H. (2006): "Autonomous inspectors in tax compliance simulation". *Proceedings of the 18th European Meeting on Cybernetics and Systems Research.*

Bloomquist, K. M. (2004), "Modeling taxpayers' response to compliance improvement alternatives". Paper presented at the *Annual Conference of the North American Association for Computational Social and Organizational Science* (NAACSOS), Pittsburgh, PA.

Bloomquist, K (2006), "A Comparison of Agent–Based Models of Income Tax Evasion." *Social Science Computer Review* 24 No. 4: 411–25.

Bloomquist, K (2011), "Tax Compliance as an Evolutionary Coordination Game: An Agent-Based Approach", *Public Finance Review*, 39: 25.

Davis, J. S.; Hecht, G.; and Perkins, J. D. (2003). "Social behaviors, enforcement and tax compliance dynamics". *Accounting Review*, 78, 39–69.

Elster, J. (1979). *Ulysses and the Sirens: Studies in Rationality and Irrationality*. Cambridge: Cambridge University Press. Reimp. 1984.

Elster, J. (1989). *Nuts and Bolts for the Social Sciences*. Cambridge: Cambridge University Press.

Kirchler, E. (2007), *The Economic Psychology of Tax Behaviour*. Cambridge: Cambridge University Press.

Korobow, A.; Johnson, C. and Axtell, R. (2007), "An Agent-Based Model of Tax Compliance with Social Networks", *National Tax Journal*, LX (3): 589-610.

Mittone, L. and Patelli, P. (2000). "Imitative behaviour in tax evasion". In B. Stefansson & F. Luna (Eds.), *Economic simulations in swarm: Agent-based modelling and object oriented programming* (pp. 133-158) Amsterdam: Kluwer.

Noguera, J.A.; Guijarro, X.; León Medina, F.J.; Llàcer, A.; Miguel Quesada, F.J.; Tapia, E.; Tena-Sánchez, J. and Vinagre, M. (2011): *Valors i actituds sobre justícia distributiva: prestacions socials i fiscalitat*. Barcelona: Centre d'estudis d'Opinió, Generalitat de Catalunya.

Szabó, A.; Gulyás, L. and Tóth, I. J. (2008), "TAXSIM Agent Based Tax Evasion Simulator", *5th European Social Simulation Association Conference* (ESSA 2008).

Szabó, A.; Gulyás, L. and Tóth, I. J. (2009), "Sensitivity Analysis of a Tax Evasion Model Applying Automated Design of Experiments", Progress in Artificial Intelligence, *Lecture Notes in Artificial Intelligence*, 5816.

Szabó, A.; Gulyás, L. and Tóth, I. J. (2010), "Simulating Tax Evasion with Utilitarian Agents and Social Feedback", *International Journal of Agent Technologies and Systems*, 2 (1): 16-30.

Zaklan, G.; Lima, F. W. S.; and Westerhoff, F. (2008), "Controlling tax evasion fluctuations", *Physica A: Statistical Mechanics and its Applications*, 387: 5857-5861.

Zaklan, G.; Westerhoff, F. and stauffer, D. (2009a), "Analysing tax evasion dynamics via the Ising model", *Journal of Economic of Coordination and Interaction*, 4:1–14.

Zaklan, G.; Westerhoff, F. and Stauffer, D. (2009b), "A multi-agent-based approach to tax morale", *International Journal of Modern Physics* C, eprint 0508.0098 at http://www.arXiv.org.

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

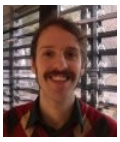
Table 1. Relevant Model Parameters

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^1	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"*

AUTHOR BIOGRAPHIES

F. J. Miguel Quesada is Associate Professor at UAB responsible for courses in Methodology for the Social Sciences, Sociology of Consumption and Applied Statistics for Marketing Analysis. He holds a PhD in Sociology from the Universitat Autònoma de Barcelona (UAB) and a University Specialist Degree in Sociology of Consumption from the Universidad Complutense de Madrid. He He has conducted research in sociology of consumption, women situation social indicators, and the school-to-work transitions. At present he mainly works in the domain of computational sociology, as GSADI member and as Director of the "Laboratory for Socio-Historical Dynamics Simulation" (LSDS), he is involved in several projects about the use of agent-based social simulation for the modelling of social networks dynamics and evolution of social behavior. His e-mail address is : `Miguel.Quesada@uab.cat` and his Web-page can be found at `http://gsadi.uab.cat/index.php/members/uab-members/fj-miguel-quesada`.

José A. Noguera is Associate Professor in the Department of Sociology at the Universitat Autònoma de Barcelona, and Director of the Analytical Sociology and Institutional Design Group (GSADI). He holds a PhD in Sociology from the Universitat Autònoma de Barcelona and has been visiting researcher at the University of California, Berkeley, and at the London School of Economics and Political Science. His research covers sociological theory, philosophy of social science, social policy, and normative social theory. He is a member of the European Network of Analytical Sociologists, and serves on the Board of the Spanish Basic Income Network (RRB) and on the International Advisory Board of the Basic Income Earth Network (BIEN). He is co-editor of *Papers. Revista de Sociologia*, and an editorial board member of *Revista Española de Investigaciones Sociológicas* and *Basic Income Studies*.
His e-mail address is : `jose.noguera@uab.cat` and his Web-page can be found at `http://gsadi.uab.cat/index.php/members/uab-members/jose-a-noguera`.



Toni Llàcer holds a FI Research fellowship -granted by Generalitat de Catalunya- to pursue a PhD project on the explanatory factors of tax evasion. He obtained a Bachelor's degree in Economics from Universitat Pompeu Fabra, a Bachelor's degree in Philosophy from Universitat de Barcelona (Academic Excellence Award), and a Master of Science in Applied Social Research from UAB. His e-mail address is : `toni.llacer@uab.cat` and his Web-page can be found at `http://gsadi.uab.cat/index.php/members/uab-members/toni-llacer`.

Eduardo Tapia Tejada is a PhD student in Sociology at the Universitat Autònoma de Barcelona and pre-doctoral researcher at GSADI. He is a graduate in Sociology from the Universidad Federico Villarreal of Peru and he holds a Master's degree in Sociological Research from the UAB. He also holds a degree in Design and Evaluation of Social Projects from the Pontificia Universidad Católica del Perú. His research interests are social network analysis, the unintended consequences of social action, the emergent outcomes of social interaction, and social simulation techniques. His e-mail address is : `eduardotapiatejada@hotmail.com` and his Web-page can be found at `http://gsadi.uab.cat/index.php/members/uab-members/eduardo-tapia-tejada`.

../