Modeling fiscal evasion in a dynamic cultural environment

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1 Introduction

Our goal is to describe the evolution of the behavior of citizens with the capability of evading taxes. Their attitude towards fiscal evasion will be linked to their nearest neighbours so that their cultural attitude towards fiscal evasion (briefly attitude) will evolve during a simulation.

For this purpose we developed an agent-base model, implemented with NetLogo, a multi-agent programmable modeling environment.

Although all agents will have have an attitude, we will split our agents in three groups: Shop Owners that will sell goods, Buyers that will buy goods and Sentinels that will make fiscal controls on Shop Owners.

They will live in a fictive world of which we can regulate parameters such as fiscal pressure or the punishment for and Evader that got discovered by a Sentinel.

1.1 Fiscal Evasion

Tax evasion is quite an age-old phenomenon that has been studied for decades, both theoretically and empirically. It can be described as the illegal and intentional actions taken by individuals to reduce their legally due tax obligations.

Tax evasion is a damage to the socio-economical environment that deprives governments of their resources and plays an important role in reducing well-being of societies. The well-known free rider problem rises when a citizen consumes public goods and services without properly contributing to related costs, causing and bad allocations of governments expenditures for healthcare, education, defence, social security, transportation, infrastructure, science and technology, as widely documented in a vast literature.

It also concern social justice, since it specially afflicts poorer people, who do not have the possibility to substitute public services with private ones available in the market at higher prices.

It is so important to deepen this field of study by extending it to a new approach, namely Agent Base Modeling.

1.2 Simulations

We will illustrate three specific type of simulations obtained with this model.

The first type, namely Mean or Average State, will have the only purpose to let us deeper understand the effects of the parameters that we can regulate in the model.

The second type of simulation will aim to reproduce and study a society in which the government policies are strongly invasive. For this reason we will refer to those simulations as harsh policies or harsh government.

Finally, we will simulate a society with a government that are softly involved in the activities of Shop Owners. We will refer to those simulations as soft policies or soft government.

2 The Model

We will divide this section in two parts. In the first one we will explain the basic mechanism of the model, i.e., we will introduce agents and their methods to exchange goods and ideas, while in the second part we will focus on the world they will live in.

2.1 The Model Structure

With the purpose of reproducing an evolving system in which a given population is allowed to break law and consequently not contributing to social capital, we first need to introduce the protagonists.

In this model we used three different types of agent turtles, namely Buyers, Shop Owners and Sentinels; the latter will be introduced after the structural things.

As you can guess, Shop Owners will be a type of agents localized on the world map with the aim of selling goods to Buyers; the latter will be instead allowed to move around the world with a Brownian motion.

From an economic point of view, we will only be interested on the profit made by Shop Owners, so we will track it, while we will assume that Buyers will always have a sufficient amount of wealth to buy goods from Shop Owners.

Their trading interaction is really simple; at each time step, Buyers will be able to buy goods from one Shop Owner in a certain range, and doing so they will give a single amount of normalized wealth to the chosen Shop Owner.

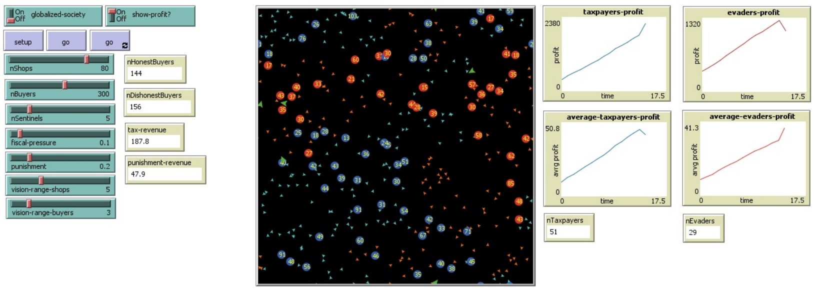

Figure 1: The View that we have during the evolution of a simulation. Shop owners can be visualized as red or blue circles, while Buyers as orange or cyan arrows. Sentinels are instead visualized as green arrows. Warm colors correspond to a 1 attitude, while cold colors to a 0 attitude.

At this point comes the main bulk of the model. As we already said, we want to simulate the attitude towards fiscal evasion of our population. This attitude will be represented in the model by a boolean variable.

All types of agents will have their attitude, and it will assume a null value if they will have a disapproval attitude towards fiscal evasion and vice versa.

For as regards Shop Owners, the attitude will determine if they will pay taxes while selling goods. For Buyers instead a null attitude will imply that they are not willing to buy goods from Shop Owners with a positive attitude, i.e., Evaders, while Buyers with a positive attitude will not look at Shop Owners attitude, and they will buy goods from whoever will be in their proximity.

As said before, attitude is a variable, and so it will change during the simulation for Buyers and Shop Owners. In this purpose will be able to adjust before the simulation starts the vision range for Buyers and Shop Owners separately, in which they will be able to identify other agents.

After a brief period of time, both Shop Owners and Buyers will start changing their attitude, but in two different ways for each other. In particular, Buyers will simply count how many agents with a different attitude are surrounded by, and if this number is strictly greater than the number of agents with their same attitude plus one, they will change attitude.

For Shop Owners instead, things are a little bit trickier. Each one of them will always track the profit of other Shop Owners, and they will change attitude in the case that the average profit of Shop Owners with a different attitude becomes grater than the average profit of Shop owners with their same attitude.

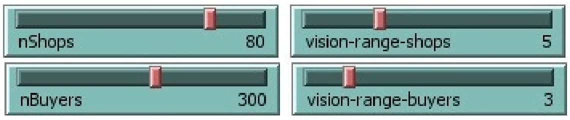

Figure 2: Parameter related to Buyers and Shop Owners that we can regulate before simulation.

It is important to notice that as soon as the world is crated, each Shop Owner will always be surrounded by the same other Shop Owners, for they are fixed in the same position for all the simulation. Furthermore, at the beginning of each simulation we will be able to set the parameters discussed until now, or the number of Shop Owners, Buyers and their respective vision ranges in which they will be able to identify the other agents to whom they are interested to.

So to recap,

- Shop Owners:
  - They are localized in a specific point of the world.
  - They have an attitude that determine if they pay taxes (0 attitude, Tax Payers) or not (1 attitude, Evaders).
  - They make a profit out of their selling.
  - They have a vision range in which they are able to identify other shop owners.
  - In the case that the average profit of Shop Owners with an opposite attitude in their vision range is greater than the average profit of Shop Owners with their same attitude, they will change attitude.
- Buyers:
  - They move with a Brownian Motion inside the world.
  - They have their own vision range in which they are able to identify other agents.
  - They have an attitude that determine if they are willing to buy goods from an Evader (1 attitude) or not (0 attitude).
  - Once per tick, they buy one single amount of good from one of the Shop Owner in their vision range, if there is one.
  - They are able to identify the attitude of agents that surrounds them, and they change their attitude if outnumbered by agents with opposite attitude.

2.2 Social Policies

Now that we have discussed the basis of the model, we can introduce the remaining parameters that let the simulations vary from case to case.

For sure, we can regulate the fiscal pressure to which Shop Owners will be subjected to, with a slider that can vary from 0 to 1, that represents the proportion of wealth that Shop Owners will need to pay to the government.

Evaders will not be forever unpunished anyways. The last type of agents that we mentioned before, namely Sentinels, will move around the world checking the attitude of Shop Owners. In case a Sentinel discovers an Evader, he will be forced to pay a percentage of his profit to the government.a

This percentage can be regulated through a slider called punishment, as the number of sentinels can be regulated as well.

Figure 3: Parameter related to government policies that we can regulate before simulation.

In this regard, it is important to notice two aspects. The first one is that Sentinels will always discover an evader, if located in a certain range. The second aspect is that the attitude of Sentinels is fixed on one. That means that this model does not take into account corruption or bargaining between Sentinels and Shop Owners.

3 The Mean State

In this section we will try to catch some aspects that we can generalize through all the simulations.

To understand what we are aiming for, lets put us in an average case, where with average we mean that we fix all the parameters that we can regulate to a mean value, with the exception of the vision ranges.

In this case we can observe that the model needs a longer time than most of other case that we can observe to reach an equilibrium, with a mean time of ~ 150 ticks.

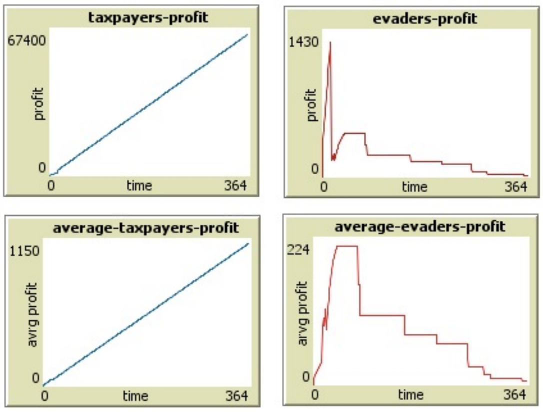

Figure 4: Results for a simulation reproducing a mean state. During the evolution of the simulation the number of evaders slowly decrease until all Shop Owners becomes Tax Payers.

But what we really mean with an equilibrium? For how we construct the model, the attitude of an agent can change only if he is in proximity of one or more agents with a different one. For this reason, when all agents will have the same attitude, they will no longer be able to change it for a structural reason; we will refer to those cases as equilibrium state.

We can have only two types of equilibrium states, the one in which all agents have a 0 attitude, briefly '0 state', and the one in which all agents have a 1 attitude, briefly '1 state'.

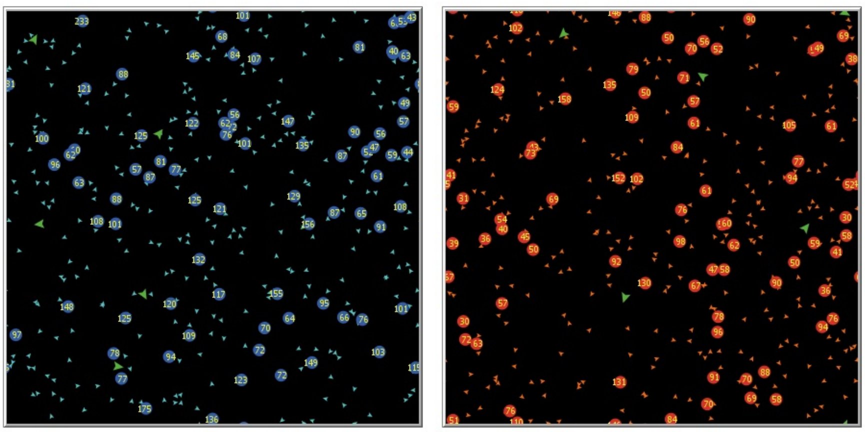

Figure 5: The two equilibrium states. On the left we have an example of a simulation that decayed toward a 0 state, while on the right we have another simulation that decayed toward a 1 state.

Let's now analyze what happen in the average case. The model overall present a dependency from the initial conditions. All agents are generated with a random attitude indeed, and that can influence the model in a precise direction.

The average case presents a strong robustness to the initial conditions anyways, and it will decay in most of the simulations to a 0 state, for which evasion becomes a spectrum of the past.

During the simulation we can observe that the world is spotted by some fictive islands, in which the majority of agents will have the same attitude, until any fluctuation, principally in the profit of Shop Owners, lead to a fast changing of an island. This particular aspects can be noticed in each simulation.

Also if the average case is not so interesting by itself, it is useful for evaluating the effects of each single parameters of its own. When we change one single parameter, maximizing the value that it can assume, we could expect that the equilibrium state that will be reached will reflect what we could expect in reality.

parameter	equilibrium state
nBuyers	none
vision-range-Buyers	none
nSentinels	0
fiscal pressure	1
punishment	0

In this sense indeed, the model show consistency with common sense. In fact, while maximising the number of Sentinels and the punishment for Evaders lead to a 0 state, maximising the fiscal pressure lead to a 1 state in literally any simulation.

Among this parameter one can notice that the the two fastest in regards of the related equilibrium time are the number of Sentinels and the punishment, that lead to a 0 state in ~ 20 ticks, while the fiscal pressure is less decisive, leading to a 1 state in ~ 50 ticks.

For as regards the parameters related to the Buyers (i.e., number of Buyers and their vision range) we can observe that, in this particular case in which all other parameters are fixed on an average value, they don't influence the simulations in any direction, also if as we will see later they will have a relevance with other combinations of parameters (see harsh policies).

Lastly, we need to understand which are the consequences of changing the parameters related to Shop Owners, namely vision range and their number itself. Instead of considering themselves separately we will for now consider themselves together, defining the connectivity as their product.

Also if changing the connectivity of a simulation does not influence directly the resulting equilibrium state, it change drastically the equilibrium time, to the limit in which a maximum connectivity makes the simulation reach an equilibrium in a single tick, and contemporary lead to a brutal sensitivity to initial condition.

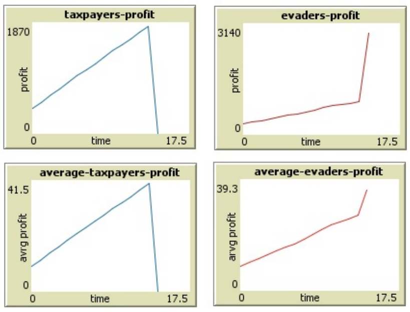

Figure 6: An example of a simulation with high connectivity (nShops=80 visionRangeShops=10). The simulation decayed quickly towards a 1 state in less than 17 ticks, showing a strong dependency from initial conditions.

Vice versa, a low level of connectivity makes the islands of which we spoke before not directly interacting, so that we can find a sort of disconnected world that reaches different equilibrium for each island (actually a world is never totally disconnected for the buyers are free to move, but their attitude rapidly adapt to the one of the island they are in proximity to).

Also if connectivity is a powerful tool to use to understand what it's really happening in a simulation, and to verify the consistency in a single simulation (for example running a simulation with a low connectivity and see if the islands will reach the same equilibrium state), we are not really interested with it.

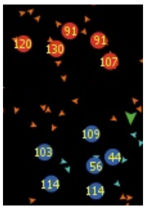

Figure 7: In this example we can see how a low level of connectivity lead to two non-directly communicating islands, in which the dominant attitude became different.

So, what are we really interested in? The most relevant simulations will be the ones with conflicting parameters, for example maximising both fiscal pressure and punishment, to see which will be the dominant equilibrium state.

3.1 Mutual Influence of Attitude

In The Model section of the paper we explained how Buyers and Shop Owners change their attitude. In particular, while Shop Owners will be only interested in the profit, an attribute that only Shop Owners posses, Buyers will count how many agents of any kind with a different or same attitude are surrounded by.

In this sense, it seems that Shop Owners have an upper hand on Buyers in regard of influencing each other for a structural reason.

Instead, also if Buyers don't influence Shop Owners directly, they influence the market itself, so that in particular if an Evader is surrounded by Buyers with a 0 attitude, they won't sell any goods.

So, which is the resulting balance of this two aspect? In general, in each simulation one can notice that on a short term, approximately of 50 ticks, Shop Owners have a stronger influence on the attitudes, so that islands around them begin to form and buyers will adapt to their trend. On the later stage anyway, the overwhelming number of buyers will start influencing the profit of the Shop Owners more drastically, and so their attitude to.

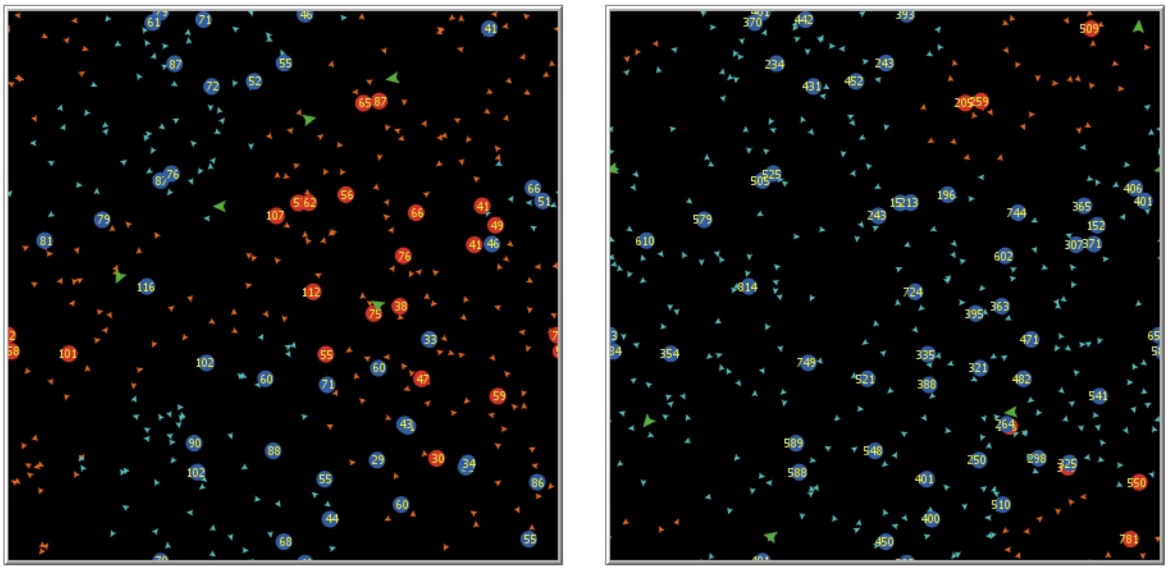

Figure 8: On the left a simulation at ~ 25 ticks. Notice that island are already formed with buyers adapting their attitude to the one of Shop Owners. On the right the same simulation at ~ 150 ticks, in which the overwhelming number of Buyers with attitude 0 made the Shop Owners to adapt to their attitude.

4 Harsh Policies

In this chapter we will analyze what will happen to the evolution of the attitude of our agents in the case that the government policies are strongly active in the market.

By saying so, we mean that all the simulation in this chapter will be done with high values for the parameters fiscal pressure, punishment and number of Sentinels.

In particular, we will fix some parameters listed below while changing only the number of buyers to see what changes when the demand changes.

parameter	value
nShops	75
nSentinels	25
fiscal pressure	0.9
punishment	0.9
vision-range-shops	5
vision-range-buyers	3

4.1 Simulations

For the harsh government, we can consistently observe that the equilibrium state is the 1 state, in which both Shop Owners and Buyers have an attitude of 1.

The equilibrium state is reached with consistency in a brief time, depending on the number of buyers.

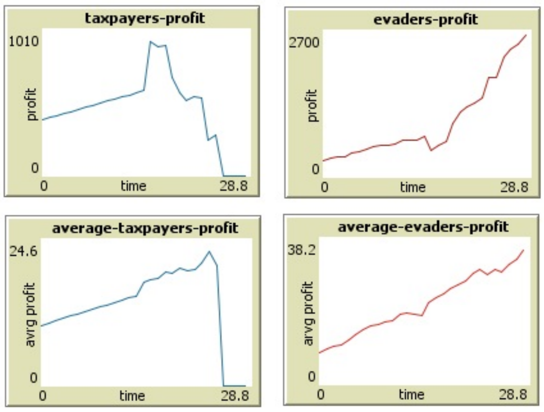

Figure 9: An example of an authoritarian simulations. We can observe that the number of Shop Owners with a 0 attitude quickly decays to zero.

What happens is that in this case, the profit made by Shop Owners are really low in comparison with all other case due to an high level of taxation and an high level of punishment.

This implies that the dominant factor in influencing other agents attitude is a short term earning strategy, in which the quick gains due to tax evasion of a Shop Owner can lead to a really quick influence on the attitude of all other agents in the nearby.

There are two important consequences that we can point out.

The first one is that these short times we are dealing with completely annihilates the possibility from Buyers to influence Shop Owners, as we already seen in the 'Mutual Influence' chapter, this happens on longer times.

The second one is that we have discovered that with an high level of taxation, the government interventions in the direction to sanction Evaders are not effective, in the sense that they don't influence the attitude of Shop Owners toward a 0 attitude to the point of changing the equilibrium state.

4.2 The Demand

In the previous section we already said that we analyzed more simulations for the harsh government varying the number of Buyers.

What we observed is that their number don't influence the equilibrium state of the harsh policies simulations, but they have an effect in the time that occurs to reach that state.

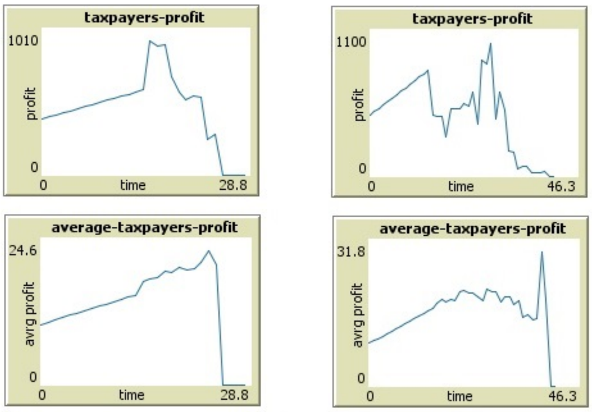

Figure 10: On the left the graphs with a low demand (nbuyers = 250). On the right the graphs obtained with a high demand (nbuyers = 600). Note that while in the first case the number of Tax Payers decays to 0 in $\sim$ 25 ticks, in the second case it takes $\sim$ 45 ticks to happen.

It could be interesting to understand if higher number of buyers can lead to a stretch of the equilibrium time so long that also in the harsh policies case we could observe a dependency of the equilibrium state from the buyers attitude, but the computational costs are higher than the ones we could afford.

5 soft Policies

In this chapter we will analyze what will happen to the evolution of the attitude of our agents in the case that the government policies are softly influencing the market.

By saying so, we mean that all the simulation in this chapter will be done with low values for the parameters fiscal pressure and punishment.

In particular, we will fix some parameters listed below while changing only the number of sentinels, as we will see this number can influence the resulting equilibrium state more than all other parameters.

parameter	value
nShops	80
nBuyers	300
fiscal pressure	0.2
punishment	0.2
vision-range-shops	5
vision-range-buyers	3

5.1 Simulations

For the soft policies, we can observe that the equilibrium state to which the system decays is not well defined, in the sense that the system statistically decays towards the equilibrium states with the approximately same probability, i.e., the probability of decaying in state 0 in a little bit higher than the probability of decaying in state 1, when the number of Sentinels is low.

Moreover the equilibrium time is higher than all other cases.

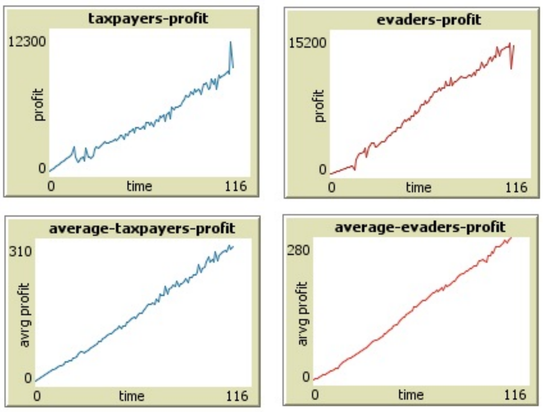

Figure 11: An example of a simulation with parameters corresponding to soft policies. We can notice that at ~ 120 ticks the system has not reached an equilibrium state yet.

Lets not try to understand why this happens.

The fact that the parameters fiscal pressure and punishment are fixed on the same values and have a low values, makes the short term profit of Shop Owners not relevant in influencing the attitude.

For this reason, the equilibrium state is reached on longer times, and as we already seen the most dominant factor on longer stages is the attitude of Buyers.

Under this lens, we can also understand why the probability of decaying to a 0 state is slightly higher than the one of decaying to a 1 state.

Indeed, while Buyers with attitude 1 will still buy goods from both evaders and taxpayers, Buyers with attitude 0 will only buy goods from taxpayers.

So, there is a natural tendency to decay to a 0 state for the simple reason that a fluctuation on the attitude of buyers in the direction of a 0 attitude will quickly void the evaders.

5.2 Forcing the Attitude

As we said before, we let the number of Sentinels varying during this type of simulations.

The reason of this choice is linked to the fact that raising the number of Sentinel is the stronger way to force the attitude of our agents.

This is due to the fact that the effect of Sentinels does not only push towards a 0 state for the fact that more fiscal controls will lower the profit of Evaders, but also because their attitude is fixed on 0, and this implies that we are breaking the symmetry between the number of agents with 0 and 1 attitude.

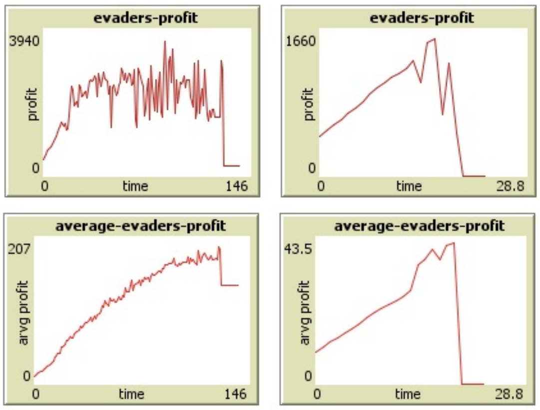

Figure 12: An example of two simulations with soft policies. The one on the left is made with 5 sentinels and the equilibrium time is ~ 140 ticks. The one on the right is made with 25 sentinels, and the equilibrium time is ~ 25 ticks.

For the fact that raising the number of sentinels have this double effect on the simulation, it is by far the most effective way to force the attitude of Shop Owners, also in comparison with raising punishment.

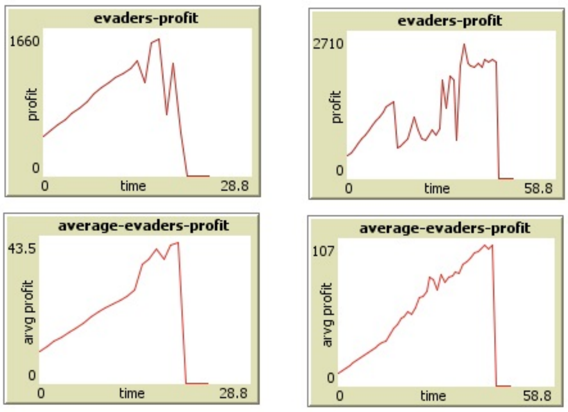

Figure 13: A comparison between two simulations. The one on the left deviates from the soft policies for the number of sentinels, equal to 25. The one on the right deviates for the punishment, equal to 1. We can see that the equilibrium time for the first one is approximately halved in comparison with the one of the second simulation.

6 Conclusion

6.1 Results

We analysed the average state reaching the conclusion that the model is solid, in the sense that modifying parameters in a direction lead to the results that we can expect from the literature or simply from the common sense.

We analysed the harsh policies and we reached the conclusion that a short term profit is the dominant strategy in that case, and that the equilibrium state in which the model decays with consistency is the 1 state, or the one in which all Shop Owners are Evaders.

Lastly, we analyzed the soft policies, and we reached the conclusion that the dominant strategy for Shop Owners is to adapt to the attitude of buyers, so that the equilibrium state strongly depend from the attitude of Buyers towards fiscal evasion.

6.2 Further Adjustments

Despite the model reproduces in a proper way the results that have been shown by the literature on fiscal evasion, it has some limits. In particular, we will point out four of them.

The first one regards the profit related to Shop Owners. In the model indeed, we consider the profit as a positive variable related to the amount of sales of goods, without taking into account the possible costs of conducting such business. From another point of view, we can assume that we are in the limit in which it is always profitable to conduct such activities, for the cost is equal to zero. For this reason, it could be possible to improve the model by introducing a new parameter related to the costs that a Shop Owner should afford, and estimate the effect that such parameter could have on the attitude of Shop Owners in the limit in which a certain attitude makes the business not profitable.

The second improvement that one could make is related to the attitude of agents. This parameter is thought as a boolean variable and, in particular, it represents the willingness of the shop owners to pay all taxes, or to do not pay taxes at all. By saying so, a certain way to improve the model could be to change nature of the variable attitude from boolean to continuum, with the purpose to represent a more complex way to evade taxes.

Moving forward on this line, we could also rethink the way with which buyers and Shop Owners change their attitude. While for the latters indeed, the mechanism with which they change attitude is related to the profit of other Shop Owners in their vision range, for Buyers it is merely related to the number of agents with a given attitude, without taking into account any form of utility, eventually related to the wealth distribution or the government capital. In the aim to improve the model, we could think to mix the two mechanism with which agents change their attitude.

Finally, we can make two considerations about the parameters and agents related to the government administration. At first, its important to point out that the attitude of the agents Sentinel is fixed on a value that makes all of them virtuosos. We could so improve the model inserting parameters describing the eventual level of corruption of the government representatives, by simply changing in a proper way the sentinels attitude from a constant to a variable. Further more, we could also question the nature of the government in this model, by replacing the related parameters such as fiscal pressure or punishment with a smart state agent that could modify those parameters tying to maximize the social capital.