Agent Based Modelling of Tax Evasion Behaviour

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Abstract

I present here the description of the model and the results obtained from the agent based model of tax evasion behaviour. I tried to develop a realistic model of taxpayers to reflect the real life tax evasion behaviour as seen under the specified rates. I have tried to examine the effect of varying audit rates and tax rates on the evasion behaviour of the agents. The model was run with maximum 1000 agents. The influence of dynamic social network is also examined from the model. Finally a few results are presented and analysed. Results are also compared with the existing estimates of the IRS [5].

Introduction

The human behaviour is very complex and they take decisions considering many factors in their mind. Their decisions are also affected by the pre-held set of beliefs and prejudices developed by them over the initial phase of life. Different people take decisions varyingly based on factors which they again perceive with varying mindsets assigning different degree of importance to them. This results in great heterogeneity in the human population. Owing to this high degree of diversity of the human behaviour for different situations prediction of human behaviour cannot be determined by simple mathematical models of homogenous agents and then aggregating it to get the mass reaction. We have to incorporate all the irregularities and variety of the decision making process of human mind. Now with the help of computers we can easily simulate multi agent systems comprising of heterogeneous agents which can help in giving a much closer picture of the human behaviour under certain conditions.

I have developed my multi-agent model to predict the tax evasion behaviour of the taxpayers keeping in mind the above mentioned high degree of variety in human behaviour. I wanted to develop a realistic model which could reflect the true effects of change in various parameters on the taxpaying behaviour of the taxpayers. The applications of such a model, once fully developed, are exciting as it could be used by tax agencies to estimate the effect their policies would have on the taxpaying behaviour of the taxpayers thus also help in general welfare of taxpayers. It would also help in better understanding of human behaviour and thought process. In my model I have used NetLogo simulation language (Wilensky, 1999) for developing the model. NetLogo is a cross-platform multi-agent programmable modelling environment. [6]
The agents in the model have about twenty different traits like lifespan, age, honesty, vision, peak-income, income etc. based on which the agents take the decisions. Most of these traits are varying and different for different agents. There are two types of agents in the model, one being service type and other being the business type, both differing in income characteristics. The model allows the user to adjust various parameters like the penalty rates, tax rates, audit rates, visibility of income, etc. There is also the option of turning the social effect on or off.

**Income and Age Characteristics**

There are two types of agents in the model one being the service type agents having whole of their income visible and the other type being the business type having the fixed percentage (can be fixed by the user) of the total income as visible. The income levels of the agents vary with their peak-income being randomly determined from a random distribution which is addition of exponential distribution with mean of six lakhs and normal distribution with mean of three and half lakhs and with variance of one and half lakhs (distribution looks as in figure 1). I have taken this distribution as most of the agents below the range of the income range are exempted from tax. Another reason for this distribution as I could see it was that only few of the taxpayers are really very rich, with majority taxpayers lying in the range of high density region in figure 1, and this proportional difference in the income doesn’t really change as the income increases but if we consider the real adjusted incomes over the time periods we would most probably get the same proportional differences. So I haven’t considered increasing the income of agents in the cycles as it would not really affect the results. The agents of the model have varying lifespan and as the age of the business agents increase their probability to earn more increases. I did this as business persons would tend to earn more as they gain experience. The income of the business type agents vary every cycle, this also I implemented based on observation that they have different profits in different time periods. Each agent is assigned a lifespan which is determined randomly from normal distribution with mean of forty-five and variance of fifteen. These lifespan are taken keeping in mind that these are active tax-paying years of normal tax-payers. When an agent ages beyond its lifespan it dies and another agents is born with random characteristics but with probability of being business type or not according to the percentage of service type taxpayers as fixed by the user thus keeping that percentage same over the time periods.

**Taxpayer Evasion Decision**

In the model of the Bloomquist (2004) \(^{[2]}\), whenever the condition,

\[
p < \frac{1}{(1+g)}, \quad \text{where} \quad g = \frac{(f+d)}{(1+\tau)}^\epsilon
\]


is true the taxpayers decide to evade. Here $p$ is audit rate, $f$ is penalty rate, $d$ is detection rate, $r$ is the discount rate and $t$ is time lag or the time period between evasion and detection. I wanted to incorporate the effects of varying of tax rate on the evasion behaviour so I modified the expression a little:

$$\text{Perceived Audit Rate} < \frac{\text{Tax Rate}}{\left( 1 + \frac{(\text{Penalty} \times \text{Detection Rate})}{(1 + \text{Tax Rate})^{\text{Time Lag}}} \right)}$$

Whenever this is true the taxpayers will evade on their non-visible income. If the condition is very bad in social network then also a taxpayer will evade, so I have incorporated this condition that if more than seventy percent of social network is evading then the agent will evade except if recently audited or under the social effect. If the taxpayer decides not to evade then he pays tax on full income. But if the agent decides to evade then for the business type agents they will evade on their non-visible income according to their honesty levels and the service type agents will evade but still on average give more than eighty percent tax.

The taxpayers generally perceive higher audit rate than actual. So to incorporate this feature into the model I have assigned each agent random perceived audit rates from a normal distribution with mean little more than the actual audit rate and a standard deviation of three percent.

**Social Network**

Man is social animal. Human behaviour is influenced a lot by their observations of what others are doing. Humans learn a lot from observing their surroundings and most of their decisions are based on the knowledge of these observations. Thus incorporating the effect of social network was necessary for bringing the model closer to the reality. In case of taxpaying behaviour picking up the analogy to the traffic example from the Bloomquist paper (2004) \(^2\), we can see that if there is speed limit fixed on the road you are driving then a lot of your decisions are influenced by what others do in this case. For example if you just saw a speeding vehicle caught by traffic police then you will not speed above the limit for quite some time till the memories of that event do not fade away and for that temporary period your perception of law enforcement has increased. Similarly if you see all the vehicles overtaking you with speed above limit and no one being caught or rather no traffic police in sight then your perception of law enforcement decreases and you too speed up till you don’t see another incident similar to that in previous sentence or you yourself aren’t caught. Thus the effect of neighbouring people is very much evident from this example.

In the previous Bloomquist (2004) model \(^2\) the social network was static. The social network had a fixed number of members. In this model I have made agents to keep moving continuously within a fixed area and the social network of the agent will comprise of all the agents that will lie within a certain fixed range of the agent. These ranges for different agents will differ and will be randomly selected from uniform random distribution from zero to the range set by the user. Since the agents keep moving in every run the network is dynamic and the number of members of social network of the agent also
keeps changing. This feature of social network can be turned on or off and also the maximum size of the social network can be fixed by the user.

When an agent is audited in the social network the agent becomes aware of this and this modifies the behaviour of the agent. The perceived rate of audit is increased by a random number of points between zero and twenty. The agent will stop evading if it was evading before this. The agent will be under these effects for a certain fixed time which is different for each of the agents and is determined randomly.

**Simulation and Results**

The figure 2 shows the interface of the model on NetLogo software.

![Figure 2 Showing the model Interface on the NetLogo](image)

As can be seen in figure 2, various parameters like tax rate, audit rate, number of taxpayer agents, penalty rate etc. can be varied by the user using the sliders. The screen also shows a switch for switching on or off the social effect. There are graphs and histograms showing the various variables like income distribution, evaders, tax-collection etc. for the runs completed. The screen also shows the agents and the area for their movement, with red ones depicting the agents who were audited and were caught evading. When an agent is audited and is caught evading, the colour of that agent remains red for five runs, as I assumed that this is approximately the time for which one would be precautionary and after that the normal rules and
situations will be the deciding factor for evasion decision. The results are for a society of thousand interacting agents in the model.

**Effect of Tax Rate**

I have modified the formula for tax evasion decision to incorporate the tax rates into it for determining the effect of varying tax-rates on the taxpaying behaviour. Although the effect is not very well implemented as yet, but still one can see that with increasing rates of taxes the number of evaders tend to increase. This would be quite natural as the amount of dissatisfaction of the taxpayers would increase with higher tax rate and they would have less to spend on themselves. This effect can be worked out better with better formulation involving greater amount of research and more data to get the desired level of correspondence with real scenario.

**Effects of Detection Rate**

The effects of varying detection rate are quite prominent due to the social effect. When the number of evaders who get audited but still tend to avoid being detected and avoid any penalty is large, the neighbouring agents also develop tendency to evade. Thus the detection rate of the audits comes into the picture here. The varying detection rates can be sign of inefficiency of the auditors as well as the corruption in the system, as the corrupt auditors will leave the evaders in exchange of some personal gain. This also relates to the perception of law and order of the country as well as the efficiency of administrative machinery. And as this perception level goes down one would stop abiding by the rules and start to think of one’s own benefits. Thus it is also clearly seen this trend is reflected in the graph.
As previously mentioned the visibility of the income for the business type can be set by the user and the audit rates can also be varied to determine the various effects on the tax evasive behaviour of the agents. The visible income is generally fully reported by the taxpayers, it is the non-visible income that the taxpayers hide. Various combinations were tested for different audit rates and different percentages of visibility of income. The results are shown in following figures 5 and 6.

![Graphical representation of results depicting evaders with varying audit rates and visibility of income when all business type agents.](image)

In this result hundred percent of the population of agents was of the business type. The results indicate gradual but large decrease in number of evaders as the audit rate increases. The results also indicate decrease in the number of evaders as visibility increases in general, but it is not consistent and not too noticeable from the results obtained from the model. These results obtained do not match very well with those obtained by Bloomquist (2004) \(^2\) in terms of variation of compliance with variations in the percentage visibility of income.

The result obtained in the next graph (figure 6) is with a population of seventy percent service type agents and rest thirty percent being the business type. The results again indicate that the number of evaders decrease gradually though not in that large numbers as in previous case because already the number of evaders is less in this case because of high percentage of service type agents. Here again we see that the variation with audit rate is very clear but the variation with visibility of income is again not very clear though it can be said that in general there is decrease in number of evaders as visibility increases, but there are inconsistencies in the results from the model.

One possible reason for this inconsistency could be that I have not taken the visibility percentage criterion anywhere in the decision process of the agents. But still for high audit rates results give the weak trend of decline of evaders with increasing visibility percentage, so it does reflect some relationship between the two. Some more amount of work can be done on this
and a little more complexity can be imparted to the model with respect to this variable and the amount of tax given and the detection dependability on the amount of tax evaded.

**Effects of Social Network**

The next result obtained examines the relationship and corresponding degree of variation of the number of evaders with varying range of the maximum network size for agents and also with varying audit rates. For this the switch for the social effect has to be switched on. The simulation is again done with thousand agents with varying network sizes and network members and making their decisions based on the events taking place in the social network. There are seventy percent service type agents.

If an agent in the social network is audited the agent goes under the indirect effect where his perception of the audit rate increases by twenty points and the agent stops evading in case agent was evading previously. This effect stays for a fixed period of time which is different for different agents. This can be considered as different level of risk averseness individuals have and thus who are more risk averse will continue to behave in an ideal manner for longer periods of time as compared to the less risk averse one or the one who will have shorter period for this effect to stay.

As it is clearly visible in the graph (figure 7), the decline in the number of evaders is large for increase in the social network size as well as also with the increase in the audit rates. This clearly tells that if one has large number of acquaintances and is
thus aware of their audits and evasions, then one will have higher risk averseness as probability of news of audits is higher in his network due to large numbers.

Figure 7 Graphical representation of variation of number of evaders with variations in audit rate and social network size.

Figure 8 shows the social effect variation. It shows the variation in number of evaders with the audit rate in two situations, one in which the social effect is on and the other when it is off. As is visible from graph the number of evaders is less at the same audit rate when the social effect is on as compared to the case when social effect is off. One more observation that can be made is that the decrease in
the number of evaders is faster with increasing audit rate when the social effect is on as compared to the case where it is off.

**Summary and Future Work**

The objective was to develop a model to reflect real life situation of tax evasion behaviour. I wanted to introduce the element of uncertainty and randomness into the model, but I think it was a bit overdone. The level of unpredictability is high. Still the results obtained have some similarity in terms of non compliance to those obtained by Bloomquist (2004) [2], but they also differ at many places. There is also similarity with the estimates of the IRS [5] which say that there exists non-compliance rate of fifteen to sixteen percent, which is approximately what the model also gives as result when audit rates are about four to five percent and the tax rate is about thirty percent.

The model is not fully developed and many more things can be incorporated in it for a better and closer estimation of the real world behaviour of taxpayers. The factors for determining the effect of tax rates on the decisions of the taxpayers can be implemented in a better way to give a more concrete and correlating result after sufficient study and research. Different tax rates for different income groups can be implemented. A level for dissatisfaction can also be implemented for each agent, which may also contribute to the taxpaying decision of the agents. Many other factors like business cycles and GDP growth, or in other words the perceived economic condition can also influence the decisions and may be incorporated into the model.

The real challenging task will be to control the randomness in the model but also taking care not completely doing away with it, and also to calibrate the model parameters so that the results resemble the real world situation and can be useful in predicting the human behaviour.

**References**


[6] NetLogo was authored by Uri Wilensky in 1999 and is under continuous development at the Center for Connected Learning (CCL) (http://ccl.northwestern.edu/netlogo/)