SOCIODYNAMICA:
An agent based computer simulation studying the interacting web of biological, social and economic behaviors

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Abstract:

Sociodynamics is an interdisciplinary attempt to study the dynamics of complex systems within the conceptual frame of subjects spanning biology, sociology, politics, history, economy and other sciences. For this purpose, the agent based computer simulation Sociodynamica has been developed to study the effect of attitudes and behaviors on aggregate wealth accumulation and other macro-economic parameters in artificial societies. The model simulates a continuous two-dimensional toroidal world through which different types of agents interact in an economically meaningful environment. The simulations test for the effect of different financial structures, such as barter, money, banks and derivatives on the ability of the virtual system to produce and accumulate wealth. Sociodynamica allows exploring the effect of heterogeneous distribution of labor, different types of organizations, variable properties of natural resources, different altruistic, emotive or rational behaviors of agents, and other features on the economic dynamic of the system. The results can be compared with known economic phenomena to test for the robustness of the assumptions used. The simulations help us in understanding and quantifying the relevance of different interactions that occur at the micro-economic level to the outcome of macroeconomic variables. Sociodynamica is proposed as an analytically useful a metaphor for a complex poly-ethic society of agents living in a free competitive market. Some concrete examples of the working of altruism, division of labor and banks on macroeconomic variables are provided. Two important results achieved so far are: 1- A precise differentiation between altruism and social investment that help clarify divergences in ongoing discussion of the subject among physicists, ecologists, game theorists, computer scientists, ethologists and economists. 2- A demonstration that optimal behavior of agents differ for different economic environments. Specifically, optimal behavior for undifferentiated hunter-gatherer economies, for agricultural societies, and for highly labor-differentiated technical societies is very different regarding optimal levels of mutual cooperation and other basic behaviors.

I. Introduction

Assuming the economic environment as a multidimensional hyperspace in which economic consequences of human action are represented, and the exchange as a way to promote social processes; then money does not appear suddenly in the economy, but as the result of pre-existing values. This is clearly the case with certain objects that assume a monetary function. In this sense, we define money as the purest expression of the concept of the economic value.

Money is then more than a simple economic concept: it is an abstraction of a social relationship that only exists in societies; societies in which private property, agents' independence, and individual responsibility for the risks they face, is present (Wray, 1996).

Following Giddens (1994), money is a token, a kind of abstraction that acts like a medium of exchange and which assumes some knowledge and trust granted on it from the ones who use it. Obviously, the use the money eases transactions because it is a well-known abstraction, which summarizes -at the moment of its acceptance- the whole group of elements that support it. For the above mentioned, as token, money is an appropriate tool in systems of growing complexity.

Theoretically speaking, in economic orthodoxy, the central function of the money is to be a medium of payment; therefore it is no more than ‘a veil ' in the economic world, an element that only facilitates the exchange. On the contrary, post-Keynesians and Circuitists, emphasize money as being generated through the credit process and its performance as token, being then, decisive in the economy.

It is difficult to specify what money is or which asset can be considered as money, because money is usually defined by its functions. Those who emphasize the credit process point out that what we call money is in permanent change, in continuous flow through the economy, and no predictable relationship among the quantity of money and the behavior of economic agents exists. Thus, the velocity of circulation of money is not constant, but volatile and essentially unpredictable. Following Gurley and Shaw (1960), we may say that the continuous financial innovations induce a growing credit readiness and an increase of the velocity of monetary circulation.

Different levels of sophistication or financial depth are known to exist, that go from systems based on barter, going through those of self-financing, simple intermediation, until arriving to systems of complex intermediation (characterized by an active management of assets and equities) with external sources. In the sophistication process, the financial innovation generates cost reductions as well as a diversification of risks, increasing the level of liquidity. On the other hand this process has proved to be crisis prone.

The influence of money creation is a key matter in economics, and it is for this reason that our goal here is to develop computational tools that allows us to simulate societies of different levels of financial sophistication, with different number and kind of agent, favoring a better knowledge of economic processes.

II. Simulation

The agent based computer simulation Sociodynamica was used to study the effect of altruistic punishment on aggregate wealth accumulation in artificial societies. A somewhat simpler version of Sociodynamica was published before (Jaffe, 2002a, b, 2004a, b). The model simulates a continuous two-dimensional toroidal world through which different types of agents wandered with Brownian motion, each at its proper speed. We refer to Brownian motion here to the fact that the direction of movement was determined randomly each time step along the two dimensional grid. The speed of this motion (m) ranged from 0-30 pixels / time step. Agents could not learn. The simulations tested only for the survival abilities of agents under variable circumstances. As dead agents were substituted by new ones, which had their parameters assigned at random, the simulations served as a way of weeding out those combination of parameters that conferred low fitness or low survival capabilities to agents, selecting those agents possessing parameters that conferred them larger survival possibilities. Agents did not inherit their parameters, as Sociodynamica is a metaphor for a society of agents living in a free competitive market.

The toroidal world was supplied with patches of agricultural land (food resources: Rf) and mines (mineral resources: Rm). Each time an agent happened to land over one of these resources while walking randomly around, they acquired a single unit (*wo*) of the corresponding resource, accumulating wealth, either as food (*wf*) and/or as mineral wealth (*wm*).

Agents spend some of their wealth in food in order to survive, consuming food at a basal constant rate (b), which was a fraction of the resource unit (*wo*). The wealth in food (*wf*) of each agent changed each time step:

$$d\mathit{wf} = -b.dt + wo \qquad \text{where } wo = 0 \qquad \text{if no resources are encountered.}$$

b determined the degree of external constraints or of competitiveness of the environment and was fixed at 0.1, indicating the speed of degradation of accumulated resources in wo / time-step. This value produced simulation outcomes that are closed to what we expect in real societies (Jaffe 2002a,c). Agents with no food resources left (wf = 0) perished and were substituted by a new agent with randomly assigned parameters. This substitution process allowed maintaining the total number of agents in the population constant.

Similarly, agents encountering minerals acquired a single unit of the resource (wo) each time they encountered it. Minerals did not degraded ($b_m = 0$). The wealth in minerals (*wm*) was inversely related to the probability of sudden death for each agent. That is, mineral wealth improved the odds of surviving external constraints. External "catastrophes" killed agents at random, each time step, and large amounts of *wm* protected the agents against these catastrophes by reducing the probability of being affected by them. Agents with *wm* = 0 could survive, though, with a lower probability. The agents were struck by a fatal catastrophe if the following relation was true:

wm < rnd(0-1) * D

So that the greater the wealth of accumulated minerals of the agent, the lower their probability of being struck by a catastrophe, at any level of danger (D). The values for rnd or the random culling were fixed externally and could vary in the range of probabilities between 0 to 1.

Agents moved in random directions each time step. Each time an agent met another at a distance smaller than 20 pixels, an exchange of wealth could occur. These could be of various types. Donations of food occurred when the difference in food wealth (*wf1-wf2*) between the two agents was larger than 2. Then the richer agent transferred food to the less wealthy. The amount of food transferred depended on the **generosity** (g) of the donating agent, which varied initially among agents from 0 to 5 deciles of their wealth (*wf*), i.e. 0 to 50 % of their wealth.

Both types of resources were replenished continuously. Each of them was concentrated in a different single patch and the total amount of resources was 200 wo for food and 100 wo for minerals. Each resource patch was distributed initially at random in the landscape but remained in the same place during the duration of each run.

In some simulations, more "**structured societies**" were simulated by modeling labor specialization of the agents. In this case, agents were subdivided into three categories. Farmers which specialized in collecting only food; miners which collected only minerals; and traders. Traders specialized in trading minerals for food when encountering a farmer, and food for minerals when encountering a miner. Traders increased the value of minerals (*wm*) they traded by 50 %. This increase in wealth simulated an "addition" of value of minerals due to "processing" or the effect of "work productivity" (see also Jaffe 2002c). When not explicitly stated, artificial societies had no structure, i.e. no division of labor, and all agents could collect food and/or minerals. No traders were simulated in non-structured societies.

Interchange of good was modeled as barter, were food could be exchanged for minerals. This could be done with or without money. Another stage of economic sophistication consisted in simulating merchants that could create money by establishing credit. A further sophistication is the establishment of central banks that charge seniority, and of more complex banks that create financial instruments according to the need for credit.

The variables of the simulation model were chosen so as to simulate separately each of the following scenarios:

- Barter: No tax no money
- Barter with only one type of agents
- Barter with three different type of agents (farmers, miners, traders)
- Barter with differential taxation where the rich agents transfer 10 % of their wealth to the to poorest

- Barter with flat tax: Each agent pays 10 % of its wealth in tax and receives the total divided by the number of agents
- Barter without tax
- Money with "species" reserve: Only money emission. No money creation but money is available at birth and used for trade. Prices are determined by demand
- Mercantile: Traders create money against goods. Fixed prices
- Mercantile: Traders create money against goods. Prices determined by demand
- Banks: Fiduciary Money

The two resources can be defined so as to make one or both of them: renewable, not renewable, predictable, unpredictable, degradable or not degradable

Mixed strategies can also be modeled but were not explored for this paper

III. Results

A great number of simulations, performed using different constraining parameters, that can be run by the reader by downloading the simulation model at (http://atta.labb.usb.ve/Klaus/Programas.htm) and running simulations, show that dynamic features, known by fundamental economic theory, can be replicated with the model. Some of the economic features that emerge from the simulations of agents in Sociodynamica are:

1- Increase of wealth is dependent on some kind of synergy in economic interactions that create wealth. Without it, wealth can not be created but only transformed, accumulated or dissipated (Jaffe 2002a, Jaffe 2004a).

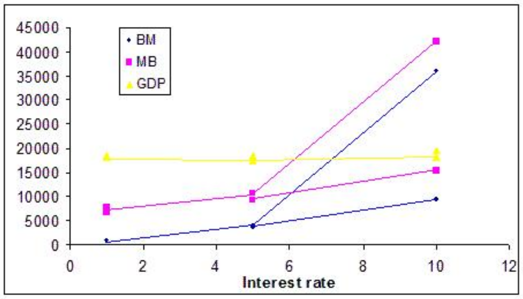
2- Money supply can affect the sustainability of economic growth

3- Financial elements of the model can gain a life that is independent to the underlying economic processes

4- Changes in worker productivity affect the structure of division of labor among the agents (Jaffe 2002b).

5- Inflation, i.e. increase of prices, is not dependent on the kind of money used but only on supply and demand. That is, money manipulation by itself does not produce inflation, unless money supply is made independent of demand.

To illustrate this last point, we present the results of simulation regarding the rate of increase of the money supply and total accumulated wealth under simulations with different fixed rate of interest rates for money lend in a Mercantile economy with banks. The main result is presented in Figure 1.



The figure shows that under different interest rates, simulations develop populations of agents that accumulate, after 200 time steps, similar amounts of wealth (GDP: aggregate wealth of all agents). However, the monetary base (MB: all money outstanding) and the amount of money in banks (BM: money only in banks) increases with increasing interest rates and at high interest rates the collapse of the financial system occurs quite frequent, leading to a high variability in the results, represented in the figure as the range of values obtained in a sample of 10 simulations. Thus, the model shows that high interest rates causes turbulence in the economy and that real creation of wealth is not directly dependent on interest rates.

In general, the model allows exploring the effect of a given variable upon macro economic parameters of choice. Some of the monetary variables that can be explored are: Prices of food and minerals, commercial profit, need for reserves in food or minerals, seniorage, interest rates, differential depreciation of resources, different levels of cooperation-competition.

The simulation exercise shows that a great number of variables are only useful in the sense that it allows to answer a great range of questions. But in order to understand the effect on the economic dynamic of a given variable, all other variables have to be kept constant and the attention in the study of simulations has to be given to maximum three of them.

IV Conclusions

This exercise shows that computer simulation of simple economic agents can generate a dynamics that resembles real life features of known economic system. Simulations of complex systems however, produce complex results that need sophisticated statistical analysis. Thus, simulation models, if they want to add to economic knowledge, have to focus on very specific and fundamental problems. The next step of this exercise is to choose a concrete, quantitative example of features in real economies to simulate them in order to gain a better understanding of the underlying dynamics. One such example could well be electronic banking, its particularities and its effect on the global economy.

The simulations based on Sociodynamica have shown that the type and nature of financial instruments is pivotal in the management of economic dynamics. This insight might be trivial for economists, but it opens a window of opportunity that hints to the solubility of complex economic problems by opening a door for the exploration of financial instruments yet to be invented.

The limitations of our simulations so far is that we have dealt only with pure competitive markets through general equilibrium modeling, ignoring imperfections in the market and heterogeneity of agents. Further research should deal with these aspects.

The simulation exercise showed that simulation models, besides having a potential in experimental economic research, area a fantastic tool to make complex phenomena visible to human understanding and thus should have a potential, if properly adapted for that purpose, in didactic games for the teaching of economics at all levels of educational and academic specialization.

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