

Monte Carlo exploration of mechanisms for the creation of aggregate wealth

Klaus Jaffe

Instituto Venezolano de Investigaciones Científicas (IVIC)
and Universidad Simón Bolívar, Caracas, Venezuela, kjaffe@ivic.ve

Abstract:

Wealth creation is the main aim of many human activities, although the creation of wealth for whole societies has eluded the efforts of the larger part of countries in the modern world. How is capital created and increased? At the individual level, this question might have convincing answers, but at an aggregate level, i.e. at the level of groups, societies and nations, the answers are less convincing. Explorations of this phenomenon with Sociodynamica, an agent based computer simulation model, suggests that some classical mechanisms that have been proposed as basic for the creation of aggregate wealth, such as reciprocal altruism, do not work without additional assumptions of the nature of economic activity. Specifically the simulations suggest that complex economic activity requires either the existence of synergistic effects for its maintenance, or for non-economic motivators as engines of economic activity.

The agent based computer simulation model Sociodynamica, creates economic agents that interact with each other in different ways (the model simulates commercial interactions, altruistic interactions, knowledge transfer, induction of motivations) and that exploit the environment in different ways. The model allows for a Monte Carlo exploration of the parameter space in a range of possible economic scenarios. The economic societies simulated include pure agricultural systems (agents exploit only renewable resources), and more sophisticated agricultural societies to which increasing complex economic activities are added, such as mining (agents exploit also non-renewable resources), commerce, and exploitation of non-material resources (such as information and knowledge).

The simulations show that an important ingredient in economics is a relationship between work productivity and division of labor, and that heterogeneous increases in work productivity across different industries affect the structure of the division of labor in the society.

Keywords: Aggregate wealth, division of labor, labor productivity, computer simulation

Introduction:

Since the seminal work of Adam Smith (1776), the fact that division of labor produces increased economic efficiency has rarely been challenged. Yet what are the factors that make an increased division of labor be more efficient? Some of these questions have been partially answered by biologists studying social insects (Oster and Wilson 1979, for example). In fact experimental data from human societies confirmed that increased social aggregates, which allow for increased division of labor, show increased efficiency in energy use (Cabrera and Jaffe, 1998 for example). Yet what are the micro-economic forces that produce synergisms when human societies divide the tasks to be performed among the individuals? This is the question I want to tackle with an agent based computer simulation.

The Model:

The agent based computer simulation called sociodynamica, available at <http://atta.labb.usb.ve/klaus/klaus.htm>, was used to study the effect of the various degrees of work efficiency (e) and environmental riskyness or “generic dangers” (d) on wealth accumulation in virtual societies. The model simulates a continuous two-dimensional spherical world in which agents search for resources (\mathbf{R}) in order to survive. Simulating a continuous sphere (the earths surface for example) eliminates any border effects in the simulations. Two types of resources were simulated “food” (\mathbf{Rf}) and “minerals” (\mathbf{Rm}) and both came in units w_{f0} and w_{m0} respectively. Each time a generalist agent or an agriculturalist agent encountered \mathbf{Rf} , it increased its accumulating wealth (w_f). Equivalently, each time a generalist agent or a miner agent encountered \mathbf{Rm} , it increased its accumulated wealth w_m . Agents

spend some of their wealth w_f in order to survive, consuming wealth at a basal constant rate (b), which is a fraction of the resource unit; whereas w_m did not degrade with time. The wealth of each agent changed each time step:

$$Dw_f = -b + w_{fo} \quad \text{where } w_{fo} = 0 \quad \text{if no resources are encountered.}$$

b determined the degree of external constraints or of competitiveness of the environment. Agents with no resources left ($w_f = 0$) perished. This can be related to the natural metaphor in which organisms die, or to the social metaphor in which companies go bankrupt and dissolve. Another source for death was d that affected positively the odds that a given agent was eliminated randomly each time step. The odd of this random elimination was inversely proportional to w_m the agent possessed. Each eliminated agent was substituted by a new one where the type of agent and the amount of w_f (1-10) and w_m (1-10) was defined randomly.

Agents displaced themselves in random directions each time step producing a Brownian motion of variable speeds depending on the value of m (range of variation from 0-30 pixels / time step). The movement simulated could represent either physical distance or a two dimensional form of social distance. Each time an agent met another at a distance smaller than a given contact radius (r : 20 pixels in the simulations presented here), an interaction could be triggered depending on the labor specialization of the agents involved and the difference in wealth ($w_1 - w_2$) between the two agents. The interactions tested with simulations were:

1. All agents were generalist, they could exploit **Rf** and **Rm** and could interchange excess w_m for equivalent amounts of w_f or vice versa with other agents. When acquiring w_m , the agent increased its wealth by the factor e
2. Agents were either **Rf** collectors called “farmers”, **Rm** collectors called “miners”, or “traders”. Here only traders could exchange excess w_m for equivalent amounts of w_f or vice versa with other agents. When acquiring w_m , only traders increased its wealth by the factor e

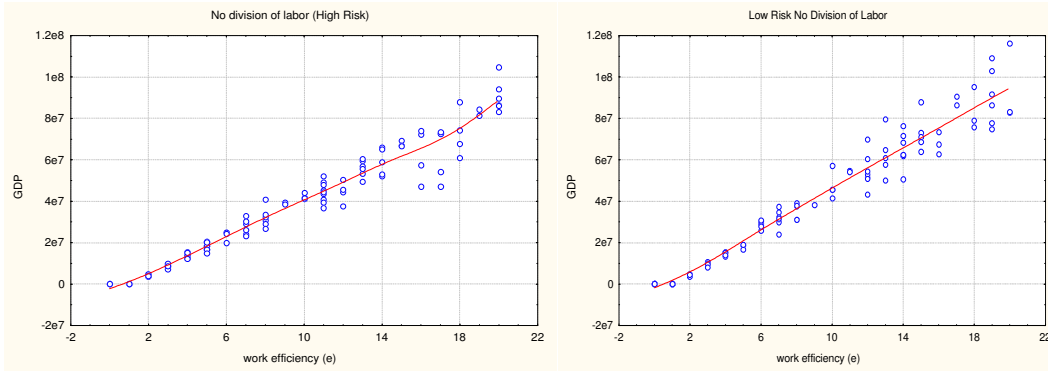
Resources were replenished each time step and were concentrated in a patch of 200 w_{mo} and 100 w_{fo} , occupying 200 and 100 pixels respectively. Each resource patch was initially located at random in the landscape and remained there until the end of the simulation.

For each simulation, the total wealth accumulated by a population (GDP, for gross domestic product) of all agents (i) was calculated as $GDP = \sum(w_f + w_m)_i$. As the simulations contained highly stochastic aspects, such as the movement of the agents and the location of the resources, at least 100 simulation were run for each graph presented here.

Results:

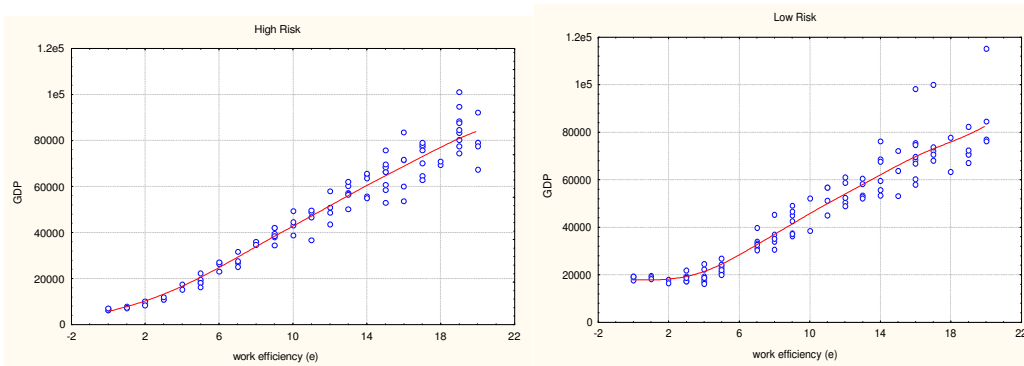
Simulations using generalist agents (no division of labor) showed that the value of d did not affect the effect of e on GDP. Simulations with high values of d ($d = 130$), indicated as High Risk show similar patterns to simulations run with low values of d ($d = 13$) indicated as Low Risk in the figures.

Simulations with no division of labor

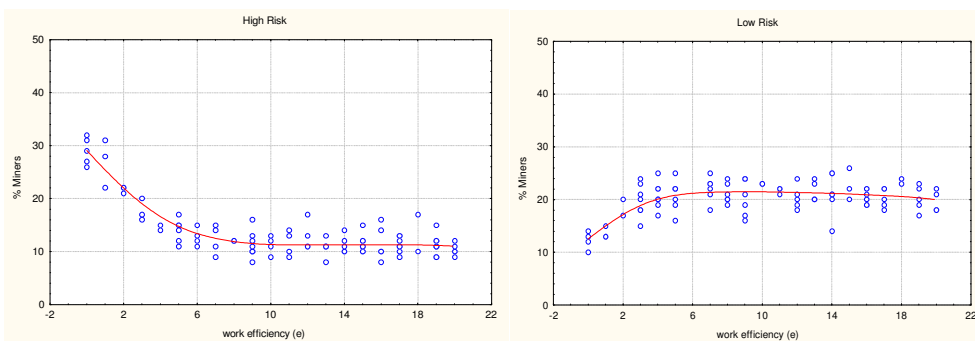


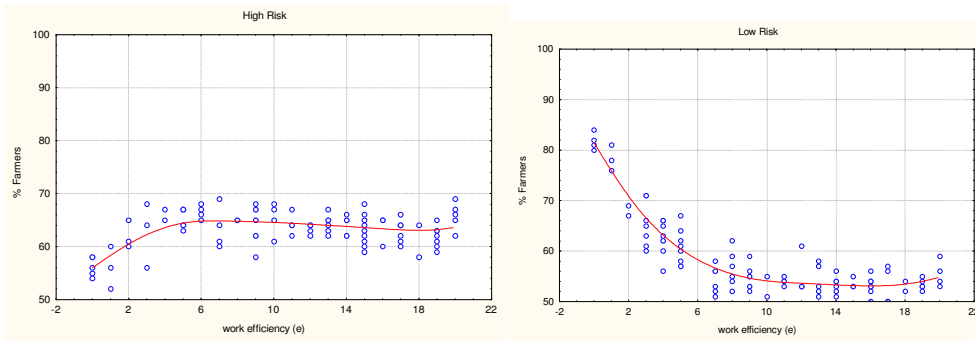
When division of labor was simulated, modeling farmers, miners and traders, the relationship between e and GDP was affected.

Simulations with 3 types of agents divided by type of labor

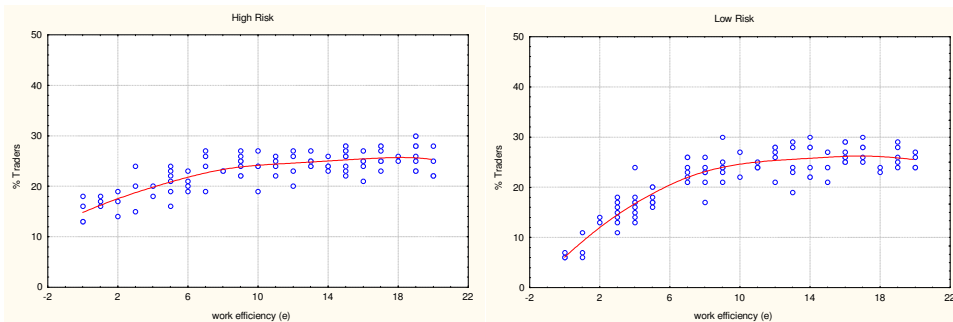


Another interesting emerging property that could be detected when simulating three different types of agents is that the proportion at equilibrium of the number of farmers and miners changed. The proportion at equilibrium of the number of farmer or miner agents that survived or got established after 100 time steps differed for different values of work efficiency (e) of the trader, and this relationship was affected by the level of risk or d . That is with large values of d , the amount of farmers decreased in relation to that of miners with increasing e ; whereas the inverse occurred with low values of d .





Yet, the proportion of traders surviving or getting established after 100 time steps always increased with increasing e , independently of the level of risk



No increase in GDP was achieved with an increase in division of labor

CONCLUSIONS:

The simulations show that with tree different type of agents, non intuitive, complex behavior emerges from the system. This does not occur with simulations using only two (not shown) or one type of agent. The example shown here reveals the effect of the ability of traders to increase wealth collected by miners on the proportion of farmers in the system. However, the model was still too simple to show an increase in aggregate wealth due to an increased division of labor.

Generalizing on these findings and applying them on what we know of the economies, I propose the following testable prediction. Unequal increases in worker productivity among different sectors of industry will produce changes in the relative importance of these industries and others in ways that can not be predicted with classical economic analysis, but that can eventually be predicted with agent based models or with equivalent computational tools.

References:

The model Sociodynamica was written in Visual Basic, is available at <http://atta.labb.usb.ve/klaus/klaus.htm> and requires a Windows environment

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