Abstract

If local circumstances can generate local social trends, it follows that global circumstances can generate global trends. Furthermore, modern global circumstances match the conditions used to create artificial evolutionary systems. If it is possible for evolutionary forces to arise in global society, then it is possible that key forces shaping global society are evolutionary in nature. We can experimentally test for the possibility of evolutionary forces in global society by using a multi-agent simulation. This paper presents a simulation programmed to capture the evolutionary prerequisites observed in global society. Trends arising from this simulation are tested against three known trends and three assumed trends arising from global society. The results from this experiment support the hypothesis that a wealth aggregation evolutionary imperative is shaping key trends in global society.

Keywords:
Evolution, Economics, Fitness Test, Evolutionary System, Aggregation

Introduction

1.1 If the shape of human society is determined solely by unencumbered individual free-will, no identifiable long-term social trends would exist. Aggregate statistics, such as crime rates, would appear as probability distributions resulting from disconnected individual decisions changed moment to moment and year to year. On the other hand, if peoples' decisions are shaped by circumstance, then long-term social trends will emerge.

1.2 There are many examples of recognisable long-term trends, such as the empirical similarity of violent crime rates throughout many European countries and cities between the years 1200 AD to 2000 AD (Eisner 2003). These trends suggest that circumstance does influence the shape of social trends in countries and cities. This possibility is supported by research in behavioural economics (Ariely 2009). More recently, Turchin, Currie, Turner and Gavrilets (2013) successfully recreated the historical emergence of complex societies in the ancient world by using a multi-agent simulator designed to emphasise two key societal circumstances.

1.3 This paper begins with the premise that globally applied circumstances will generate global trends. One set of shared circumstances arises from the nature of the modern world economy. Specifically, the free-market empowers people, organizations and countries relative to how much wealth they individually possess or otherwise control. Were these conditions to be placed into an artificial evolutionary system, a wealth aggregation fitness test would result. If it is possible for global society to generate evolutionary forces, then modern global society could be under the influence of a global wealth aggregation evolutionary imperative.

1.4 Successful wealth aggregation in a closed system requires wealth to become concentrated in the hands of the successful aggregators. Therefore, the presence of successful wealth aggregation will necessarily result in wealth inequality. The strength of the evolutionary forces will be evidenced by the degree of inequality.

1.5 Wealth aggregation will be revealed by elevated levels of starvation among poorly performing wealth aggregators, especially if this occurs in the presence of abundant food supplies. In addition, a practical disregard for sustainability is predicted to occur because freely available long-lasting goods act to equalize wealth and thus contradict wealth aggregation. Much of the eco-system is predicted to decline as it is increasingly dismantled and converted into the protected individual wealth necessary for wealth aggregation.

1.6 All the situations described above are present in modern society and all are predicted by the presence of a wealth aggregation fitness test. The key role played by the fitness test can be demonstrated by examining fitness tests in established artificial evolutionary systems.

Fitness Tests in Artificial Evolution

2.1 A key characteristic of artificial evolutionary systems is the fitness test. The fitness test determines the primary problem evolutionary processes will solve. In the absence of a fitness test, artificial evolutionary systems default to a self-replication evolutionary imperative (Zykov et al. 2005).

2.2 Hills (1998) used a number sorting fitness test in his evolutionary system. This empowered his agents relative to how well they sorted numbers. Starting with agents made up of randomly generated computer code, evolutionary processes resulted in number sorters that challenged the best human designed programmes (Johnson 2001, p. 173). In addition, Hills (1998, pp.146–147) notes:

‘One the interesting things about the sorting programs that evolved in my experiment is that I do not understand how they work. I have carefully examined their instruction sequences, but I do not understand them. I have no simpler explanation of how the programs work than the instruction sequence themselves. It may be that the programs are not understandable – that there is no way to break the operation of the program into a hierarchy of understandable parts.’

Hills’ observation concerning the potential power of evolutionary solutions must be balanced by Lipson's (2005, p. 22) observation that, ‘evolutionary algorithms do not provide guarantees on solution optimality, and do not always find the optimal solution.’

2.3 Lipson (2005) used a mobility fitness test in his evolutionary system. He began by programming the physical characteristics of such things as the rods and actuators necessary to build ‘bodies’. He added the raw materials necessary for the agents to evolve programming to control the body. This provided the means for his agents to simultaneously evolve a body and the means to control it. Lipson then created agents randomly made up of these bits and applied a mobility fitness test. The mobility fitness test resulted in agents evolving an increasing ability to move. Lipson physically built some of evolved designs in order to demonstrate that they worked in reality.
Agents

Wants

The full list of agent variables is available in Appendix C. The design of the ‘mutation’ process is explained in Appendix E. An iteration of agent behaviour can be seen in the flow chart below.

The UN claimed that 58% of all modern human deaths were caused by effects of starvation (Ziegler 2001). However, this 2001 starvation figure appears not have been supported, challenged or followed up by subsequent research. It is possible that a definition of starvation has yet to be established for the purpose of empirical research.

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The simulation runs are compared to known and inferred trends in global society. This simulator possesses a simple environment populated by agents with a high degree of behaviour variability. This allows for evolutionary selection to take place. System dynamics are designed to cause two fitness tests to emerge in succession; self-replication and then wealth aggregation.

Figure 1. Image of robots evolved in Lipson’s artificial evolutionary system featuring a mobility fitness test. (Lipson 2005, p. 9)

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An Agent's Iteration

1. Begin
2. Begin new iteration
3. Selectively conduct each activity in determined order
4. Harvest Needs [and create wants] or Harvest Wants
5. Move?
6. Yes, Move
7. No, Complete all economic tasks?
8. Yes, Explore
9. No, Calculate inheritance
10. Find 1 surviving child?
11. Yes, Give inheritance to nearest agent and die
12. No, Give inheritance to child and die
13. End
14. No, Death?
15. Yes, Reproduce?
16. Yes, Hatch 1 child
17. No, Give % needs, % wants, % money to child
18. Begin new iteration
19. Determine unique order of business
All the runs are initiated with 1,100 agents possessing randomly generated characteristics. Trading is enabled on the 700th iteration. This allows agents to establish their trading behaviour before wants appear in the system. The process of trading is explained in Appendix F.

For non-renewable runs, the choice to harvest wants is introduced to 15 random agents on the 1700th iteration. This allows the system to slowly adapt to what is a radical change of behaviour. If all agents are simultaneously introduced to want harvesting, the system tends to experience a drastic population decline, sometimes to the point of extinction.

In renewable runs, agents are able to convert needs into wants at a ratio of 10 needs into 3 wants. This ability is initiated in 15 random agents on the 1700th iteration. The manner in which agents obtain wants is the only difference between renewable and non-renewable runs.

In these simulations, a want economy cannot appear before the 1700th iteration. However, in this simulation it is possible for the want economy to remain dormant for thousands of iterations after the 1700th before becoming dominant.

To facilitate the exact reproduction of all the experiments referred to in this paper, random number generator seeds are used to control three factors: the generation of agent sets, the environment, and the initial state of agents’ decision-making. Each of 115 simulation runs features a unique combination of these three factors and this combination is subsequently used to identify each unique run. Each unique combination is run twice; once as a renewable economy and once as a non-renewable economy.

These experiments were run on NetLogo version 5.0.4 (Wilensky 1999) using the Societal Simulator v203.

This model can be downloaded here: http://www.openabm.org/model/3960/version/1/view

The simulator will be tested against three known global trends and three presumed trends. The known trends are population, per capita oil extraction, and the Gini coefficient. The three presumed trends are starvation, per capita food supply and life span. Except for population and per capita oil extraction, historical charts are not available. Therefore, the experimental goal is to determine the extent to which all six trends emerge when a wealth aggregation fitness test is invoked.

For thousands of years before the industrial revolution, the population remained within a relatively narrow band. Once the industrial revolution began, the population dramatically increased.
4.26 Significant oil production is a recent phenomenon, lasting only about 100 years before peaking. It is the dominant non-renewable energy source in modern society. Note that everything past 2010 is presumed data. Matching the trend succeeds if the simulator’s per capita extraction significantly elevates and peaks while the population continues to grow.

4.27 Milanovic (2012, p.8 footnote) says, ‘Our knowledge of the long-run evolution of global inequality is indeed very tentative, as far as its exact levels are concerned, but very clear as far as broad tendencies since the mid-19th century: the Industrial Revolution, by creating a massive divergence between the rich Western countries and the rest of the world, has pushed global inequality up.’ A successful match is an elevated Gini Coefficient while the non-renewable economy is dominant.

4.28 The act of wealth aggregation in a closed system, such as the world economy, is equivalent to wealth concentration. Therefore, successful wealth aggregation will necessarily create inequality. This relationship allows us to use the Gini coefficient as an indication of the presence and strength of wealth aggregation forces in the system.

4.29 A search failed to locate robust research on world starvation rates. Regardless, we can infer that modern society has a starvation problem. In spite of the presence of abundant food supplies, at least 1 in 8 people in the global community are malnourished (FAO 2012). In addition, the nature and frequency of world-wide charity drives is evidence of continuing starvation crises. Therefore, the simulator will be examined for evidence of elevated starvation.

4.30 A successful non-renewable economy is predicted to increase the per capita food supply because of increased productive capacity. Per capita food supply is required in order to create the context for starvation. A rise in starvation while the food supply is dropping is not remarkable. However, rising starving in the presence of a rising food supply necessarily indicates aggregation activity.

4.31 In the absence of medicine and disease, the shift from a self-replication evolutionary imperative to a wealth aggregation evolutionary imperative is predicted to cause the population’s average life span to drop (because an aggregation imperative chooses aggregation over everything else, including life). This is frequently the first chart to respond to changing fitness tests in the system.

4.32 The main presentation of the simulation charts is seen below:

Figure 5. World Gini curve from 1960 to 2010 (Milanovic 2005, pp. 180–81).

Figure 6. A) population, B) per Capita Productivity, C) Gini Coefficient, D) Life Span, E) Food per Capita, F) Cause of Death charts for the simulation run with random seed settings: agent set 590, environment 580, agent behaviour 0.

Notes for figure 6:
1. The Random Seed Settings indicate the seed settings for the random number generators controlling the creation of the agent set, the environment, and the decision making of the agents respectively. See the ‘Reproducing the Experiments’ section.
2. The per Capita Productivity takes the sum of the harvest of wants and needs and divides it by the population. In non-renewable runs, testing indicates that once the baseline...
The results for each individual run is listed in Appendix A.
Aggregate Results from Non-Renewable Runs

5.2 100% of the runs exhibit the following experimental benchmark trends:

1. rising population
2. sharp rise in per capita productivity
3. increased Gini coefficient
4. increased starvation
5. increased food supply
6. decline in life span

Conclusion

5.3 The behaviour of 115 non-renewable simulation runs supports the hypothesis and satisfies the 1st experimental objective.

Stability Test Results

5.4 Each simulation run was initiated using a unique combination of agent sets, environment, and agent's decision-making. Settings for each of these three groups were sometimes held the same in order to test the effect of changing each group in isolation. None of the three groups exhibited undue influence (see Appendix A).

5.5 The following chart lists the total number of unique settings used in each of the following groups: agent sets, environment, and agents' decision-making.

| Random Generator Seed   | Number of unique settings |
|-------------------------|---------------------------|
| Agent Sets              | 32                        |
| Environment             | 40                        |
| Agents' Decision Making | 47                        |

5.6 100% of the simulation runs exhibited the benchmark trends predicted by the hypothesis. Therefore, altering the agent sets, the environment, or agents' decision-making did not prevent the predicted tendencies from appearing.

Conclusion

5.7 The predicted tendencies are robust and support the hypothesis. This satisfies the 2nd experimental objective.

5.8 Two examples of typical non-renewable runs:

![Figure 9](http://jasss.soc.surrey.ac.uk/17/3/3.html)

Figure 9. A) Population, B) per Capita Productivity, C) Gini Coefficient, D) Life Span, E) Food per Capita, F) Cause of Death charts for the following random seed settings: agent set 2, environment 1, agent behaviour off.

![Figure 10](http://jasss.soc.surrey.ac.uk/17/3/3.html)

Figure 10. A) Population, B) per Capita Productivity, C) Gini Coefficient, D) Life Span, E) Food per Capita, F) Cause of Death charts for the following random seed settings: agent set 9, environment 3, agent behaviour 30.
Aggregate Results from Renewable Runs

5.9 Testing for the presence of key indicators of a wealth aggregation imperative:
- 10.4% exhibit an increasing Gini coefficient.
- 5.2% exhibit an increasing Gini coefficient, increasing food supply, and increasing starvation.

Conclusions

5.10 Renewable simulation runs fail to consistently exhibit the predicted effects of wealth aggregation. This supports the hypothesis.

5.11 The following are two typical renewable runs:

![Graphs of Population, per Capita Productivity, Gini Coefficient, Life Span, Food Per Capita, and Cause of Death for two sets of random seed settings.](http://jasss.soc.surrey.ac.uk/17/3/3.html)

Examine Extreme Behaviour in Non-Renewable Runs

5.12 Two elements significantly impact the shape of the non-renewable runs. One is the 'burn rate' of the non-renewable resources. If a non-renewable population use up the wants relatively slowly, the population rise will be atypically large. The simulation population was 6036 when stopped.
5.13 Note that even though the *per Capita Productivity* has peaked, there are significant quantities of wants left to harvest.

5.14 An additional effect of the slow 'burn' of wants is a relatively small Gini coefficient increase. This indicates the aggregation imperative is weak in this system. This is supported by the relatively small impact on the life span and starvation rates. It should be noted that the sudden drop in starvation and corresponding rise in life span evident in these charts occurred before the 1700th iteration.

5.15 If using wants relatively slowly causes a large population increase, it follows that consuming wants quickly will tend to stunt the population growth. The simulation population was 677 when stopped.

5.16 Notice there is little non-renewable resource left to harvest. Also, the rapid use of non-renewable resources result in a relatively high Gini-coefficient, high starvation, and a rapid *per Capita Productivity* peak.

5.17 'Culture' is the second element that impacts the system. During typical non-renewable runs, a single 'culture' appears to rise up and dominate its environment. The simulation population was 1618 when stopped.
When a single culture dominates, the resulting charts tend to be smooth and the population tends to rise with more vigour. On the other hand, when two or more 'cultures' are struggling for dominance, the resulting charts tend to become relatively jagged and the growth processes become inefficient. The simulation population was 513 when stopped.

The population curve exhibits a relatively shallow slope and follows a wobbly progression. In the 'culture' charts you can see various 'cultures' struggling for dominance.

In the following run, there are two cultures struggling for dominance – culture 1 and 6 in the Trading Culture 1 chart. When culture 1 overtakes culture 6, a distinctive kink appears in the population curve. The simulation population was 578 when stopped.
5.21 The non-renewable run that looks the least like human society features strongly competing ‘cultures’. In the run below, the Gini coefficient indicates that the wealth aggregation imperative is rising and falling chaotically. The population fluctuates. The overall result is a weak and somewhat chaotic population growth that does not closely match the human population curve. It only just manages to capture the tendency of a rising population. Notice also that Trading Culture 2 agents remain prominent in this non-renewable run. This may be an example of an evolutionary system failing to find the optimal solution.
Exchanging Renewable Runs Exhibiting Wealth Aggregation

5.22 The following two sets of graphs demonstrate the strongest Gini coefficient rise exhibited by any of the renewable runs.

Figure 25. A) Trading Culture 1 and B) Trading Culture 2 charts for the following random seed setting: agent set 9, environment 3, agent behaviour 130.

Figure 26. A) Population, B) per Capita Productivity, C) Gini Coefficient, D) Life Span, E) Food per Capita, F) Cause of Death charts for the following random seed setting: agent set 600, environment 600, agent behaviour 0. Renewable run.

Figure 27. A) Trading Culture 1 and B) Trading Culture 2 charts for the following random seed setting: agent set 600, environment 600, agent behaviour 0. Renewable run.
5.23 The precise factor(s) causing the relatively strong expression of the wealth aggregation imperative in these renewable runs is unknown. It is interesting to note that both these runs experience a single ‘culture’ dominating the environment once the renewable want economy is activated. It is possible that the newly dominating ‘culture’ possess characteristics leading to a naturally higher Gini coefficient than the ‘cultures’ it replaces. This is suggested by the fact that the rise of the Gini coefficient tends to match the rise of the dominant culture.

Testing the Simulation Integrity

5.24 It is important to ensure that the programming used to allow the agent to harvest wants past the 1700th iteration is not intrinsically generating the benchmark trends. This possibility can be explored by examining trends generated by agents with active want harvesting code in absence of non-renewable resources.

5.25 The following simulation is run to 6000 iterations. Only agents possessing want harvesting codes remain in the post non-renewable economy. However, these agents possess no wants after 3000 iterations. Therefore, a wealth aggregation imperative cannot be operating in this timeframe. It can be observed that all the charts have returned to near the original base lines. Therefore, it can be concluded that the programming used to facilitate want harvesting is not intrinsically creating the benchmark trends.

http://jasss.soc.surrey.ac.uk/17/3/3.html
5.26 It is also important to establish whether wealth aggregation forces are actually present in the simulation. Evidence for the aggregation forces can be found by examining the 'Trading Culture' charts. If wealth aggregators are being selected by an evolutionary fitness test, then a rise in the Gini-coefficient should tend to coincide with the rise of Trading Culture 1 agents. This is because agents in Trading Culture 1 are intrinsically better wealth aggregators than those belonging to Trading Culture 2.

- 89.6% of the non-renewable runs saw Trading Culture 1 dominate the system during the growth of the want economy.
- 2.6% of the non-renewable runs saw Trading Culture 2 dominate the system during the growth of the want economy.
- 7.8% of the non-renewable runs saw a mix of cultures in the system during the growth of the want economy.

5.27 In renewable runs, there are no wants to harvest. Therefore, there are no differences between the behaviour of Trading Culture 1 and Trading Culture 2 agents in renewable runs. As such, the hypothesis predicts a more even distribution of 'Trading Cultures' in renewable runs.

- 37.4% of the renewable runs saw Trading Culture 1 dominate the system during the growth of the want economy.
- 32.3% of the renewable runs saw Trading Culture 2 dominate the system during the growth of the want economy.
- 30.3% saw a mix of cultures in the system during the growth of the want economy.

This provides evidence that wealth aggregators are being preferentially selected by a wealth aggregation fitness test in non-renewable systems. That fact that Trading Culture 1 agents are being favoured by non-renewable economies is consistent with the hypothesis.

5.28 Below are two examples of agents from Trading Culture 1 exerting their dominance during the rise of non-renewable economies:

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Final Comments

6.1 The experimental results provide strong support for the hypothesis. Even in the face of changing agent sets, changing environments, and changing decision-making, the simulated trends remain robust and continue to match trends established by modern society.

6.2 Consider some of the most serious problems facing humanity today. Global society has experienced high levels of starvation in the presence of abundant food (FAO 2012). The world is experiencing a rapidly declining eco-system (UNEP 2012). Wealth inequality is intensifying in many of our most advanced countries in spite of empirical evidence that this harms society at all levels (Wilkinson 1996). As has been widely reported, the presence of habit-created diseases, such as obesity, is intensifying in many modern countries. Decades after the first warnings were made public there have been no serious attempts to counter the possibility of man-made climate change. All these events are progressing exactly as a wealth aggregation hypothesis predicts.

6.3 The hypothesis suggests that in order to make real progress in creating a sustainable and prosperous society for everyone, we first need to address the presence of a wealth aggregation imperative. It could be that the worst of humanity's 'modern problems' are the result of global evolutionary forces shaping modern society to ensure the maximum performance of the wealth aggregation agents populating the world.

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Appendices

Appendix A - Results of Each Simulation Run
Appendix B - List of Patch Variables
Appendix C - List of Agent Variables
Appendix D - Simulation User Instructions
Appendix E - How Mutation Works in the Simulation
Appendix F - How Trading Works in the Simulation

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