TAINTER INSPIRED MODEL OF SURVIVAL AND COLLAPSE OF SIMPLE HIERARCHICAL SOCIETY NETWORKS

A PREPRINT

Florian Schunck*
MLU Halle
XYZ, 12345 leipzig
florian@schunck-online.com

Marc Wiedermann†
Potsdam Institute for Climate Impact Research

April 17, 2019

ABSTRACT

In the past twenty years several events disrupted global economics and social well-being and generally shook the confidence in the stability of western societies. Popular examples are, the financial crisis, bankruptcy of multiple developed states, populism, war and climate refugees or Brexit. With this background we aimed to identify drivers of societal instability or even collapse. For this purpose a model was developed inspired by the theory of the collapse of complex societies. A simple network model simulated the development of complexity in terms of an administration body as a response to stresses affecting the productivity of the network agents.

We were able to illustrate societal collapse as a function of complexity measured in the share of administration in a network. Furthermore, we identified minimum requirements of the administration and the societal network topology to improve well-being of the society, estimated in terms of produced energy per capita. Finally we provide a mechanism for improving well-being and survival of the modeled society by enabling agents to randomly change between labor and administration, which is effective at very low rates.

Keywords First keyword · Second keyword · More

1 Tainter today

1. Observations of heavy administration bodies and bureaucracy in contemporary societies and associated problems https://www.researchgate.net/profile/David$_{S}teensma/publication/259608225_{I}mpact_{o}f_{C}ancer_{R}esearch_{B}ureaucracy_{o}n_{I}nnovat$
$of - Cancer - Research - Bureaucracy - on - Innovation - Costs - and - Patient - Care.pdf$

more

*

†

2. Theory of tainters marginal productivity Economic explanation for collapse diminishing marginal returns (a) reduced advantages of complexity (b) increased costliness of complexity ((c) increasing disadvantages of complexity)

3. Combination of economic theory and runaway model of a society which will not change course. (Positive feedback loops)

2 Model description

2.1 Tainter inspired network of a runaway society steering into deminishing marginal returns and collapse

The object of our study is a simple society that has access to an arbitrary resource a, which is a placeholder for any sort of energy source.

The society has N members, represented by the nodes of an undirected network. The complexity of the society is modelled by hierarchical societal classes. Each node can be a labourer L, an administrator A, or a coordinated Labourer L_c, which simply means being neighbour of an administrator. A high administration share is regarded as a high complexity.

Only members of L and L_c contribute to the use of a, which the society needs for survival. Administrators increase the efficiency of their labouring neighbours (who are therefore members of L_c) but do not contribute to the production/survival directly. The energetic output of the society is measured as Energy per capita, E_{cap}:

$$E_{\text{cap}} = a\,\frac{|L| + |L_c|^e}{N}, \tag{1}$$

where e is the efficiency increase exponent for neighbours of administrators. The society has an interest in maintaining the energy output above a certain threshold T.

In the basic model version, a (initially set to 1) is reduced by a percentage stress s at each time step, $a_{\text{n+1}} = (1 - s)\, a_{\text{n}}$.

s represents what Tainter calls *problems to solve*, such as population pressure or changing environmental conditions. If $E_{\text{cap}} < T$, the network reacts by adding another node to A. The first administrator is chosen randomly from all nodes with highest degree. Every following administrator will be chosen randomly out of the set of L_c with highest degree. If E_{cap} falls under a set death energy level, the simulation ends.

First, the general behaviour of the model was examined using a BarabÃąsiâĂŞAlbert preferential attachment network and compared to the predictions of Tainter's theory. For this, we distinguished between two different assumptions concerning the development of hierarchy in a society: The first is that a society chooses to form an administration class in order to increase the energy output to a higher level, without any external pressure (and continues this strategy). This means that $s = 0$ and $T > 1$. The second presumption, which is used by Tainter, says that a society has no choice but to increase complexity in order to solve problems; therefore, a constant stress rate $s > 0$ enforces a reaction even without high ambitions of the society.

In a second part of analysis, the influence of the most important parameters was scanned, taking into account the following network types:

Network type	Parameters
BarabÃąsiâĂŞAlbert	m (number of edges to attach from a new node to existing nodes)
WattsâĂŞStrogatz	k (number of nearest neighbours), r (rewiring probability)
ErdÅŚs-RÃľnyi	p (probability for edge creation)

To ensure comparability, the parameters were chosen such that the mean degree is identical. In a third step, the effect of a simple model extension was studied, which is the introduction of a population development mechanism.

2.2 random class exploration as a countermeasure to collapse on a individual basis

2.3 Analytic approximation to the mechanistic probabilistic models

3 Results and Discussion

3.1 original Tainter dynamics

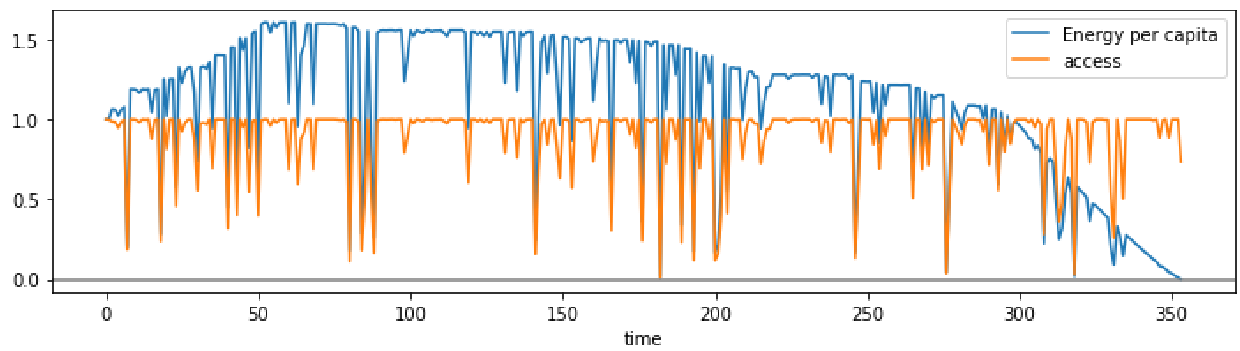

Figure 1: Example of development of a society without capacity of exploration (i.e. random change from work to adminstration and vice versa).

Exemplary development of a tainter inspired society

Interplay between network characteristics. Conditions for a beneficial administration Find out realistic ranges of efficiency and link density in simplistic societies, in order to be able to discuss the graphic

Macroscopic approximation of original Tainter Dynamics $\mathrm{P}_e = 0inordertoleaveoutexplorationterm$

3.2 modified Tainter dynamics. Exploration

model run description

Low exploration results in highly increased survival times

extension of macroscopic approximation

4 Conclusion

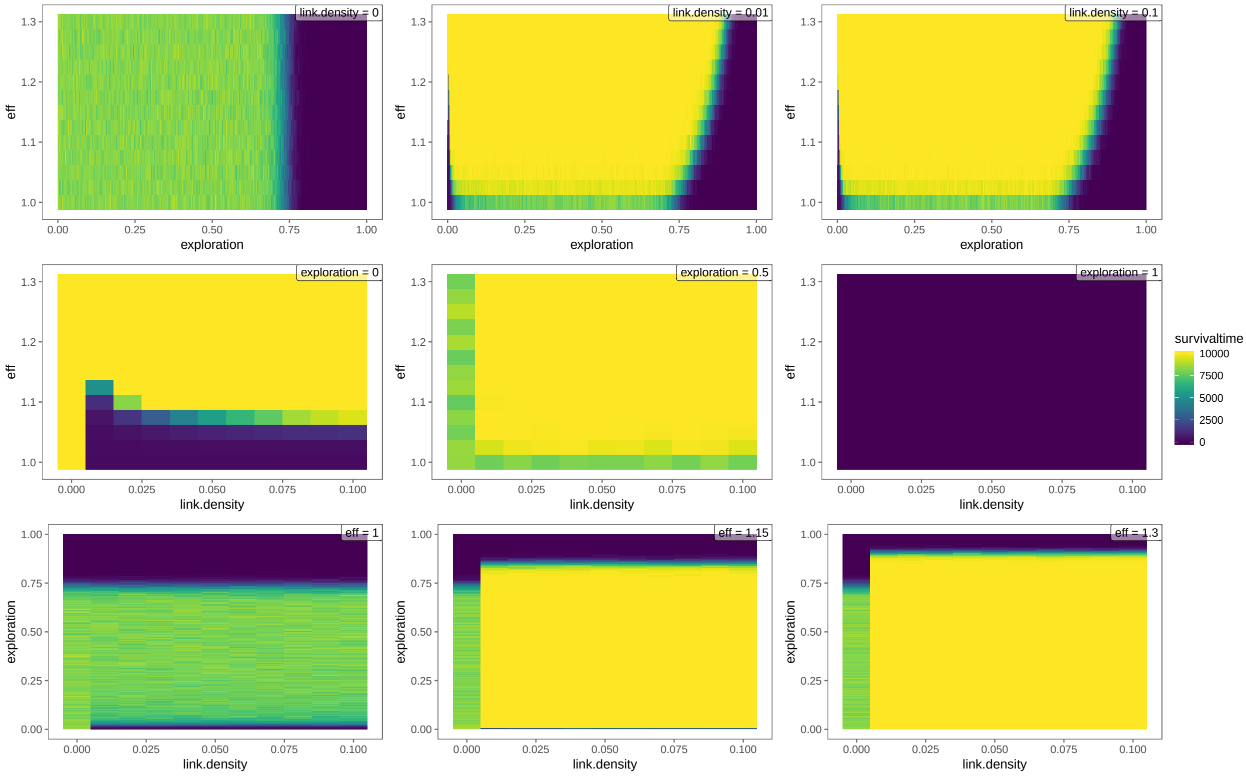

Figure 2: Survival of a network with N = 400 as a function of exploration, link density and efficiency.