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Cognitive biases and the Matthew effect: an overview and simulation

"For to every one who has will more be given, and he will have abundance; but from him who has not, even what he has will be taken away" (Mt, 25:29)

These lines describe a phenomenon that is also found in the world of science, which we decided to analyze starting from the articles written by the renowned sociologist Robert K. Merton. Two will be the main points examined in this paper: on one hand the reward system of science, i.e. the public recognition of a scientific achievement by qualified peers; on the other hand the accumulation of advantage and disadvantage among different environments. Our chosen way to provide a quantitative prediction on the Matthew effect is through a study on citation number of a set number of scientists: a MonteCarlo simulation has been performed to show the mechanism of formation of long tails typical of a Pareto distribution.

1

Cognitive biases are psychological phenomena that occur when our brain adopts mental shortcuts to solve a complex problem. In the world of science, the Matthew effect originates from a set of said cognitive biases.

2

The **Matthew effect** as a set of cognitive biases:

- Anchoring bias
- Availability heuristic
- Status Quo bias
- Confirmation bias
- In-group bias
- Self-fulfilling prophecy
- Halo effect

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In our **mathematical model**, we consider a fixed number of scientists and assign to each one a number of citations: models of this type typically start from the **kinetic theory of gases**, where the leading equation is the Boltzmann equation. In our case, the variables of the equation change from thermodynamic properties to citation numbers.
According to our model, **more cited scientists interact more**, giving rise to a rapid fall in the distribution of our sample of 1000 scientists with respect to the number of citations.

The Inspiration of St. Matthew, Caravaggio (1602)

3

In concrete terms, the Matthew effect is found in the fact that the probability of being published increases for already accomplished authors, while decreases for those yet unknown even in the case of contributions of comparable quality → the **reward system in science** is the most affected by the Matthew effect

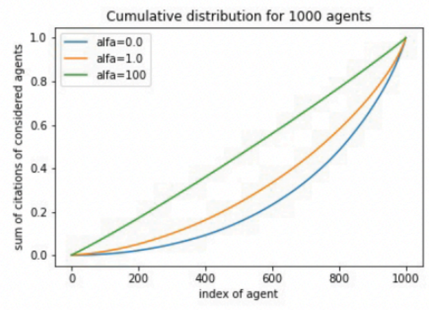
4

The Matthew effect has as its direct consequence the **accumulation of advantage and disadvantage**: in particular, the system of citations and references in scientific articles causes inequality among scientists and thus impacts **scientific productivity**:
less citations → less funds → less research possibilities → less results
As well as:
more citations → more impact → more funds and recognitions → more impactful research → more results

6

In conclusion, the Matthew effect can be studied in depth, but it remains a difficult phenomenon to control. Be that as it may, one can investigate useful behaviours and practices to reduce its effects. A couple of examples would be:

- **launching** and **empowering** lesser known and underrepresented scientists with groundbreaking ideas
- having an **anonymous peer-reviewing boards**



We plot the **Lorenz curves at different values of α**: we reach the highest level of inequality for α=0 or close to 0, while a uniform distribution of "wealth", i.e. citations, for high values of α. The Gini factor is defined as 1 – the value of the integral subtended to the Lorenz curve.

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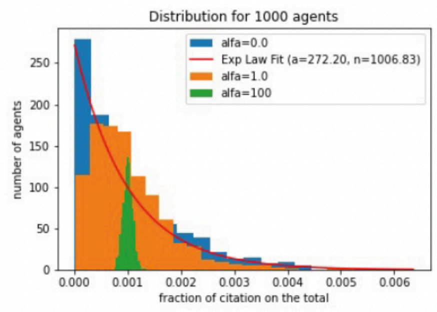
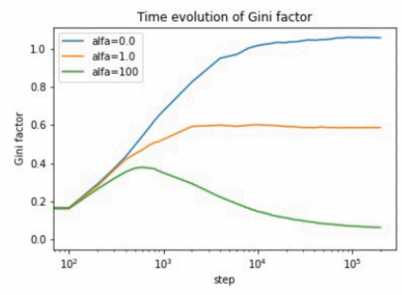
5b

We consider an **α coefficient that "uniforms" the wealth distributions** giving rise to a simil-gaussian distribution for high α values. On the contrary, for low values of α the distribution is exponential.





5c

We plot the **time evolution** of the **Gini factor**, which shows how much a given distribution deviates from a perfectly equal distribution. For **small values of α** it tends to a finite, **non-zero value**, while for **high values of α**, after a small rise the Gini factor decreases to zero.