

Population models

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Previous studies-application of distributed computing

- Avalanche dynamics
- Analysis of aggregation phenomena of micro-particles (picture data processing)
- Reconstruction of 3D surfaces

Classification of population models

- Statistical physics
- Complex systems
- Stochastic processes
- Many body Interactions
- Computer models are useful to verify hypothesis

Forgotten paper

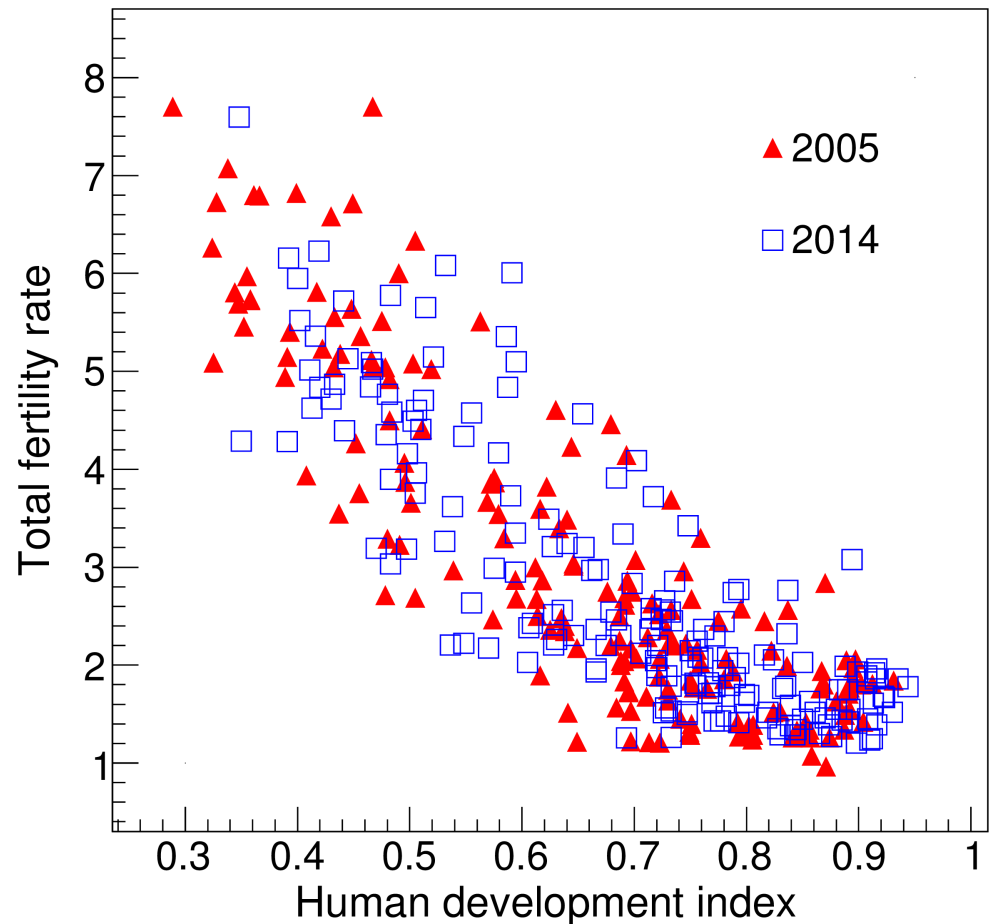
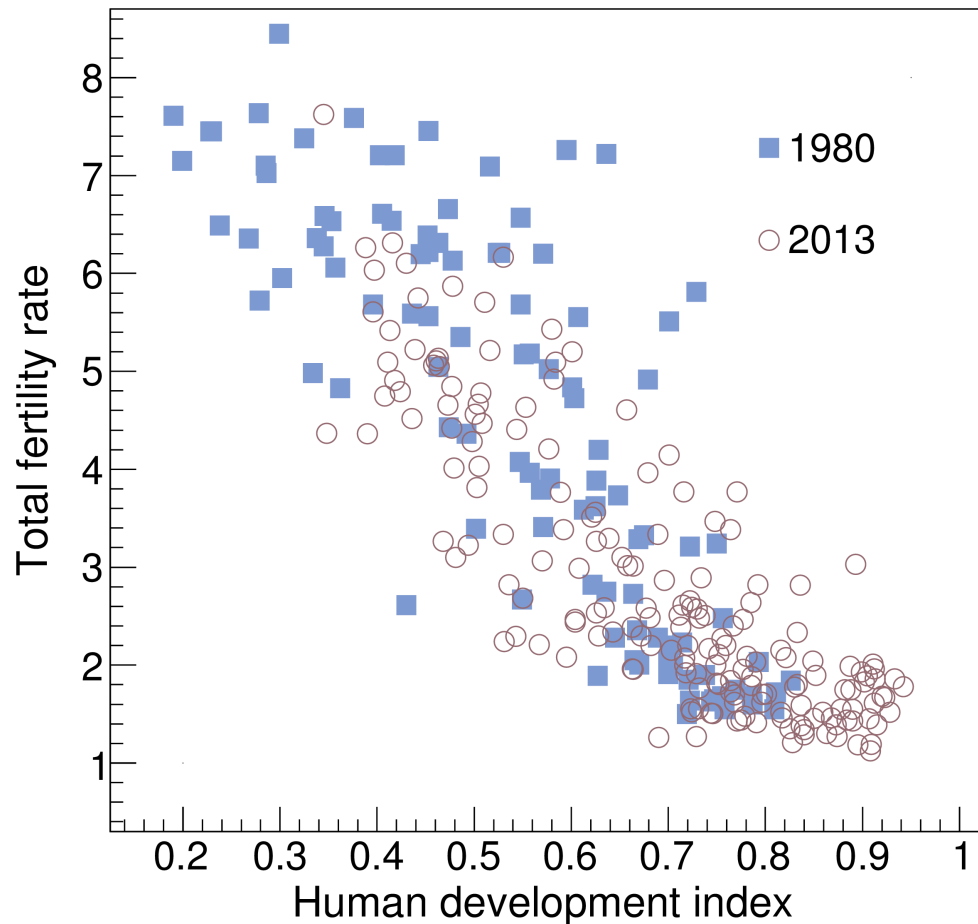
- Goodhart CB. **World population growth and its regulation by natural means**. Nature (1956) 178:561–5.

Definitions of the TFR and HDI

The Total fertility rate (TFR) is an average number of children that would be born to a woman over her lifetime

The Human development index (HDI) is a summary measure of the average achievements in key dimensions of human development: a long and healthy life, being educated and have a decent standard of living. The HDI is a geometric mean of normalized indices for each of the three dimensions.

TFR vs HDI



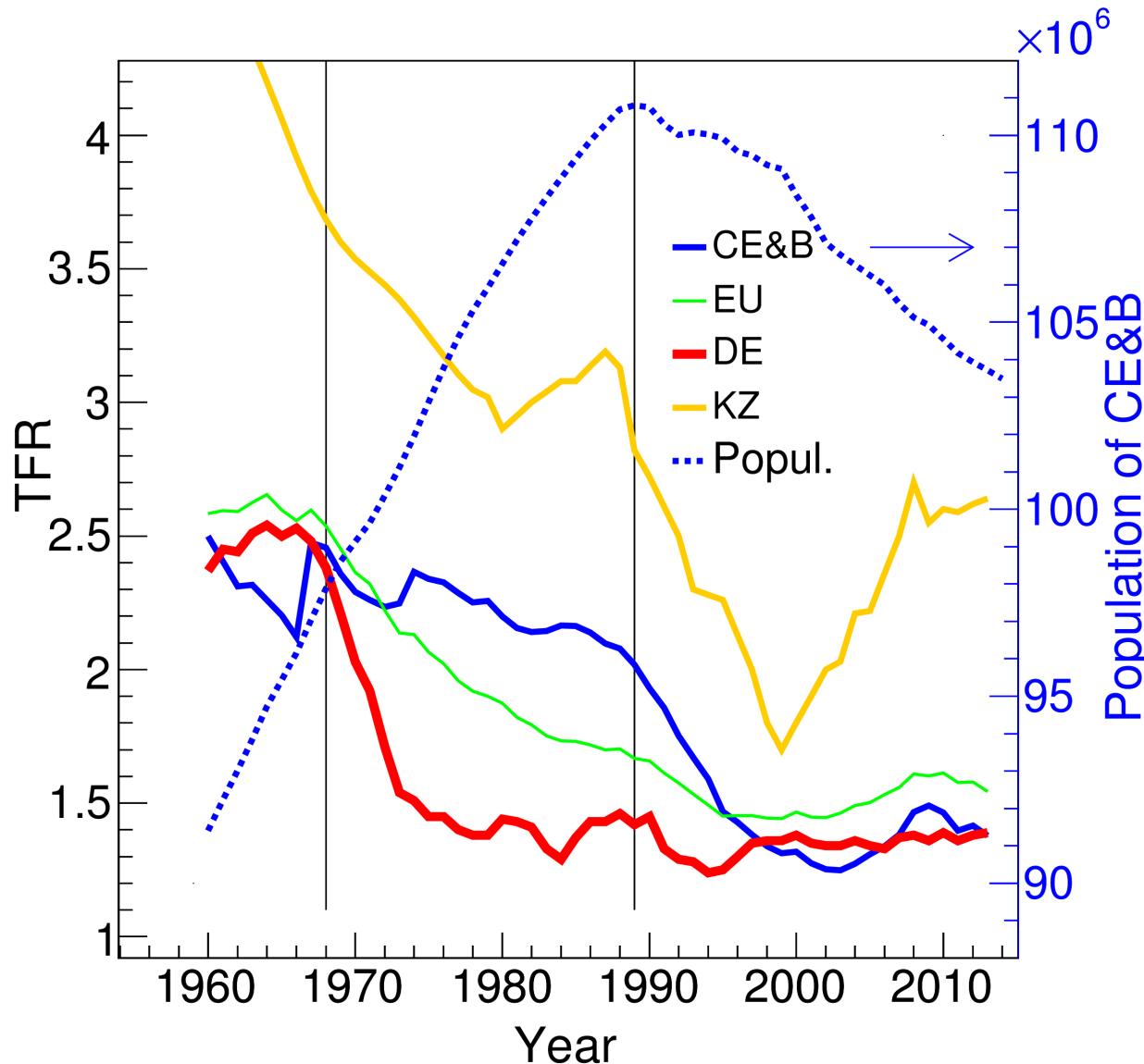
Cross-sectional relationship between the Total fertility rate and the Human development index in (A) 1980 and 2013, then in (B) 2005 and 2014.

Spearman's rank coefficients

Spearman's rank coefficients r_o with significance P are arranged in the format $r_o (P)$. The values of r_o are statistically significant if $P < 0.05$

Year	HDI < 0.85	HDI \geq 0.85	0.7 \leq HDI \leq 0.85	0.7 \leq HDI \leq 1.0
1980	-0.836 (0.0)	-	-	-
1990	-0.857 (0.0)	-	-	-
1995	-0.825 (0.0)	0.485 (0.1850)	-0.146 (0.3260)	-0.255 (0.1170)
2000	-0.830 (0.0)	-0.059 (0.8200)	-0.218 (0.1600)	-0.120 (0.3630)
2005	-0.845 (0.0)	0.500 (0.0100)	-0.308 (0.0280)	-0.288 (0.0110)
2010	-0.834 (0.0)	0.307 (0.1100)	-0.385 (0.0010)	-0.400 (0.0001)
2011	-0.836 (0.0)	0.308 (0.0970)	-0.374 (0.0016)	-0.364 (0.0002)
2012	-0.835 (0.0)	0.244 (0.1780)	-0.396 (0.0008)	-0.422 (0.0001)
2013	-0.815 (0.0)	0.217 (0.2320)	-0.412 (0.0004)	-0.457 (0.0001)
2014	-0.825 (0.0)	0.190 (0.2800)	-0.431 (0.0002)	-0.288 (0.0002)

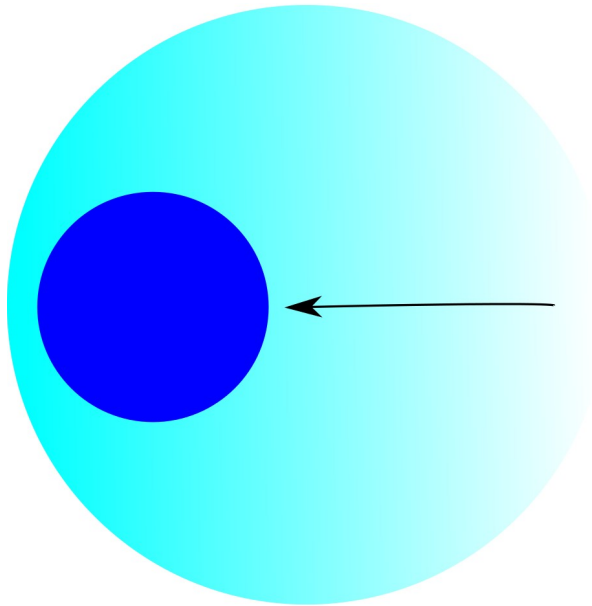
Decline of the total fertility rate (TFR) and population (Popul.)



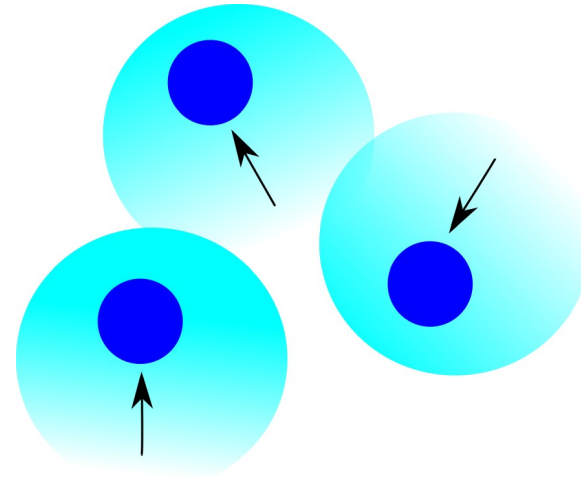
Decline of the total fertility rate (TFR) and population (Popul.). Trends in TFR (left y axis) of European Union (EU), Central Europe, and the Baltics (CE&B) and population of CE&B (right y axis). The list of CE&B countries: Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovak Republic, and Slovenia. For comparison, TFR of Germany (DE) and Kazakhstan (KZ) are shown. Kazakhstan is a former USSR country that was affected by the end of the Cold War, however shows a turn to the safe TFR. Vertical lines show important historical events, i.e., Prague Spring in 1968 and removing the Iron Curtain in 1989.

Spatial distribution of production and usage

(A)



(B)



Spatial distribution of production and usage. Arrows show labor mobility, core (a wealth territory) is dark blue and periphery (a poor territory) is light blue. (A) Core-periphery economic structure. (B) The same territory as is shown in (A) is divided into smaller self-sufficient and cooperative territories of production and usage to slow down mobility.

A Possible Impact of Economic Regulations on TFR-Hypothesis

- Core-periphery urban areas are ubiquitous in nature, for example a castle–lower castle, city–suburbs, USA–Europe, North–South hemispheres. They show the common universal underlying phenomenon of their formation, i.e., a selforganization of complex systems that reflects economic and power rules in societies
- We consider long-term low TFR < 1.5 for such unwanted state of a complex system, i.e., the state could be a consequence of economic regulations to reach sustain economic growth and low unemployment in societies.

Model specification

- The model consists of many F and M individuals that interact with one another and with environment through diverse interactions for example, economic and social.
- Multiplication of individuals, F and M, mimics a sexual connection, and F could breed the next generation.
- Similarly, their instincts mimic basic human instincts and they can learn and evolve.

Model specification-continued

- Let us consider that individuals belong to multi-layered economic, social, cognitive, and other networks, then they are considered to be nodes of these networks.
- Each network has own topology, development rules and properties of links. Each link has assigned a variable that is proportional to the strength of the interaction between nodes.
- Nodes can move in the space and create different space arrangements, i.e., aggregates, networks, etc.
- The strength of interactions among nodes can evolve depending on unspecified factors like distance between nodes, or link history.

Low Economic Safety of F and M

In developed world, most of F (M) individuals work and have high living standards. A detailed view shows that their prosperity is really very unstable and depends on many factors like a permanent income, personal savings, loans, wealth, capital, etc.. If individuals lose their job and remain unemployed for a long time their living standard gradually decreases due to low savings and after a certain time they are socially isolated. Most of F (M) individuals evaluate this situation as a serious threat to their survival.

Equality of F and M

A society promotes an idea of equality between F and M strongly and does not recognize biological differences between them when they compete for the same working position. This obliges F to behave like M and live without descendants. It is evident that a choice of F to have descendants has a negative impact on her presence in the economic network and this influences her survival (see the previous case). Her choice is significantly biased.

Collective Experience of F and M

Another important case could be a collective experience (illusion) of F (M) obtained by learning (changes of node functions) that in high living standards it is easier to survive without descendants. Generally, there are many other reasons that influence F in her choice

Conclusions

- Time series of the TFR show that the TFR trends in Europe are very sensitive on integration and globalization efforts as well as economic regulations
- We believe that radical changes of global economy are needed to increase the low TFR. This will stimulate self regulation and evolution toward the safe TFR.
- The changes should initiate the evolution toward more uniform spatial distribution of production of wealth and capital, more uniform distribution of usage, increase in a number of self-sufficient and collaborative territories, increase of individual savings, and capital, decrease of labor mobilities, decrease of inequality and careful consideration of economic regulations, and a biological nature of women fertility in economic and social actions

Recommendation 1

- The empirical relation between the TFR and the HDI, and its universality in developing countries with $HDI < 0.74$ could lead to a new strategy of international organizations to increase the HDI in these countries. Current strategies are focused only on two items of the HDI, i.e. better education of girls and higher quality of health care (prevention of HIV and other diseases). It is also necessary to enhance the third dimension of the HDI, i.e. improve living standards (see definition of the HDI).

Recommendation 2

- We assume that societies in medium developed ($0.7 < \text{HDI} < 0.85$) and highly developed ($\text{HDI} > 0.85$) countries should be more active in searching for the new economic and social models that will stimulate a self-regulation of the TFR5 around the safe replacement level.

References

- Cernak J (2017) The Evolutionary Approach to Understand Human Low Fertility Phenomenon. *Front. Phys.* 5:11. doi:10.3389/fphy.2017.00011
- Myrskylä, M., Kohler, H. P. & Billari, F. C. Advances in development reverse fertility declines. *Nature* 460, 741–743 (2009). DOI 10.1038/nature08230.