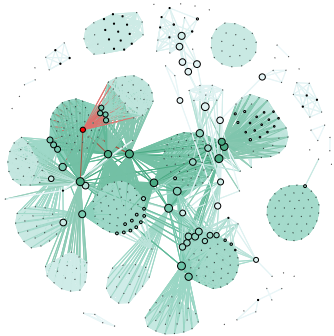




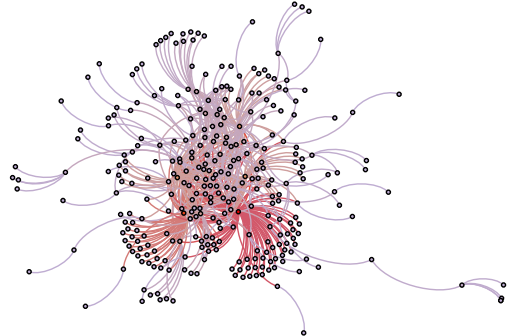
What is the productivity of research teams?

Frank Schweitzer

Collaborations - The Source of Success?



Scientists (Co-authorship networks)



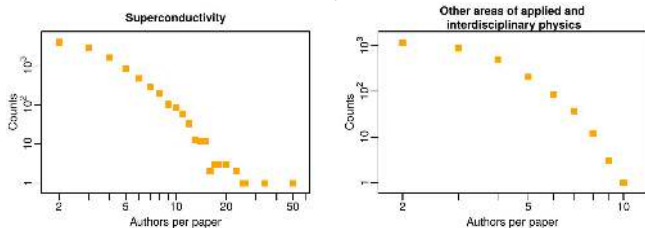
Software developers (OSS projects)

APS (1895-2004): 226'724 authors, 1'567'084 collaborations
MSAS (1996-2008): 160'891 authors, 5'324'330 collaborations

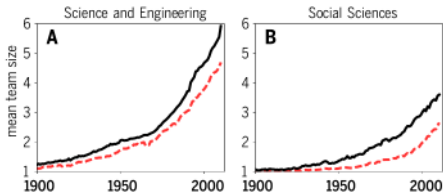
GitHub: 1.5 TB
Sourceforge: 360'000 developers, 340'000 projects, monthly for more than 10 years

How large are teams? A skewed distribution

Coauthors/publications

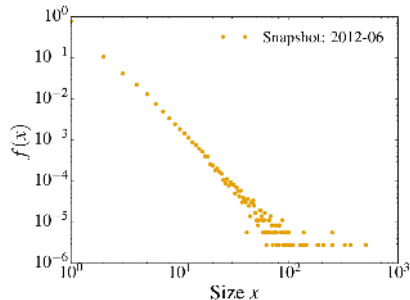


Vaccario *et al.*, EPJ Data Science (2017)



Fortunato *et al.*, Science 359 (2018) 1007

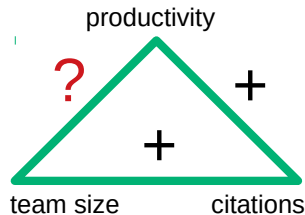
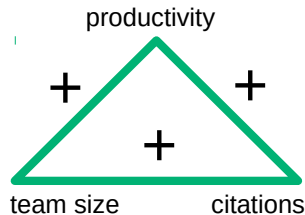
Developers/project



Schweitzer *et al.*, Advances in Complex Systems (2014)

Productivity of research teams: A “frustrated” problem

- **productivity** \neq **success** (# citations)
 - socially biased, incentives for *“more of the same”* (main stream) vs. *“radically new”*
 - depend on discipline, age, community size, citation culture ...
- **productivity** \neq **output** (# papers)
 - more papers per author, shorter papers (“letters”), results scattered across many papers
 - depend on research type (exp./theor.), publication culture (proc./journals)
- **team size** \rightarrow **productivity** \rightarrow **citations** \rightarrow **team size** \rightarrow ...
 - virtuous/vicious cycle does not work \Rightarrow *teams of all sizes*



Help from software engineering: Brooks' Law

- old problem
 - *software project management/ software economics*

“Adding manpower to a late software project makes it later.”

Fred Brooks (1975)

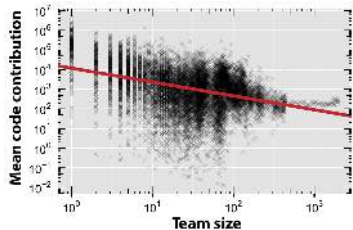
- *Deutsche Übersetzung:*

“Was ein Mitarbeiter in einem Monat schafft, schaffen zwei Mitarbeiter in zwei Monaten ...”

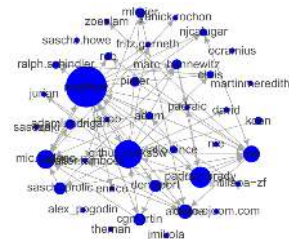
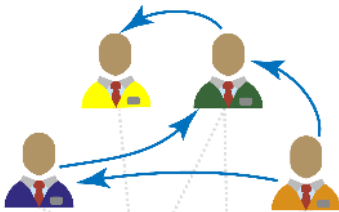
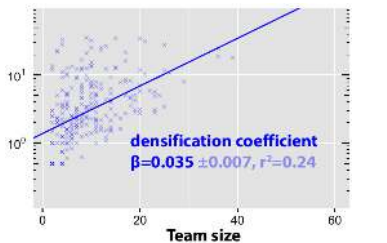


Fred Brooks image: CC-BY-SA SD&M

Productivity of software developer teams



- **robust log-linear regression:** $\alpha = 0.86 \pm 0.02$
 - productivity Y **decreases** with team size X :
 - $X \times 2.0 \Rightarrow Y \times 1.1$ (for OSS projects!)
 - large variations across projects
- reason: **increasing coordination effort**
 - density of coordination network increases with team size



I. Scholtes, P. Mavrodiev, F.S.: From Aristotle to Ringelmann: A large-scale analysis of team productivity and coordination in Open Source Software projects, *Empirical Software Engineering* 21 (2016) 642-683

Bad news for productive research teams?

① Need of appropriate productivity measures

- suitable candidates?? ⇒ **open research question**
- in the mean time: *raise awareness* that
 - **productivity** ≠ **output** (# papers)
 - **productivity** ≠ **success** (# citations)
- fight against **wrong incentives** for output/citation maximization

② Explore the role of leadership

- if larger teams are less productive, then
 - improve **motivation**, reduce **coordination**,
 - enhance “*network effect*”: synergies from more collaboration
- avoid the trap of **centralized control**
 - increase in performance comes with loss of *robustness*

